

# WIM System Field Calibration and Validation Summary Report

Texas SPS-1  
SHRP ID – 480100

Validation Date: August 15, 2013  
Submitted: October 11, 2013



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## 1 Executive Summary

A WIM validation was performed on August 14 and 15, 2013 at the Texas SPS-1 site located on route US-281, milepost 34.0, 9.2 miles north of SR 186.

This site was installed on February, 2005. The in-road sensors are installed in the southbound, righthand driving lane. The site is equipped with bending plate WIM sensors and an IRD DAW WIM controller. The LTPP lane is identified as lane 4 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on January 25, 2011 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances' however, the loop sensors have been set to maximum sensitivity by TXDOT in order to capture trucks with less trailer mass such as logging trucks. This has created a situation where the system is providing a wide range of overall length errors and is sometimes reporting two vehicles as one, which results in a higher level of Class 15 (unclassified) vehicles. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, There were no pavement distresses noted that may affect the accuracies of the WIM system. A visual observation of the trucks as they approach, traverse, and leave the sensor area did not indicate any adverse dynamics that would affect the accuracy of the WIM system. The trucks appear to track down the center of the lane. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. It appears that the high loop sensitivity setting is preventing the system from providing consistent overall length measurement. The summary results of the validation are provided in Table 1-1 below. The wide range in errors may be attributed to the pavement distress located approximately 345 feet prior to the WIM scales.

**Table 1-1 – Post-Validation Results – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	$\pm 20$ percent	$-2.5 \pm 7.0\%$	Pass
Tandem Axles	$\pm 15$ percent	$0.5 \pm 6.4\%$	Pass
GVW	$\pm 10$ percent	$0.0 \pm 3.6\%$	Pass
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.3 \pm 3.4$ ft	FAIL
Vehicle Speed	$\pm 1.0$ mph	$1.2 \pm 3.0$ mph	FAIL
Axle Length	$\pm 0.5$ ft [150mm]	$-0.1 \pm 0.3$ ft	Pass

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was  $1.2 \pm 3.0$  mph, which is greater than the  $\pm 1.0$  mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of -0.1 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

This site is not providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 3.8% is greater than the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 5.4% from the 110 truck sample (Class 4 – 13) was due to misclassifications of Class 9 vehicles.

There were two test trucks used for the post-validation. They were configured and loaded as follows:

- The Primary truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with concrete blocks.
- The Secondary truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard tandem spacing on the tractor and on the trailer. The Secondary truck was loaded with crane counterweights.

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 9). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

**Table 1-2 – Post-Validation Test Truck Measurements**

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.7	10.5	16.5	16.5	17.1	17.1	12.2	4.3	31.4	4.2	52.1	59.0
2	68.6	10.3	13.8	13.8	15.4	15.4	11.8	4.3	29.0	4.1	49.2	56.7

The posted speed limit at the site is 75 mph. During the testing, the speed of the test trucks ranged from 59 to 73 mph, a variance of 14 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 87.0 to 128.3 degrees Fahrenheit, a range of 41.3 degrees Fahrenheit. The sunny weather conditions provided the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 27 shows that there are 6 years of level “E” WIM data for this site. This site requires no additional years of data to meet the minimum of five years of research quality data.

## 2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from August 1, 2013 (Data) to the most recent Comparison Data Set (CDS) from January 27, 2011. The assessments performed prior to the site visits are used to develop expected traffic flow characteristics for the validation.

### 2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 27 shows that there are 6 years of level “E” WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2006 to 20112.

**Table 2-1 – LTPP Data Availability**

Year	Total Number of Days in Year	Number of Months
2006	272	10
2007	246	10
2008	240	8
2009	300	11
2010	333	12
2011	312	12
2012	151	5

As shown in the table, this site requires no additional years of data to meet the minimum of five years of research quality data. The data available at the time of this study does not meet the 210-day minimum requirement for calendar year 2012.

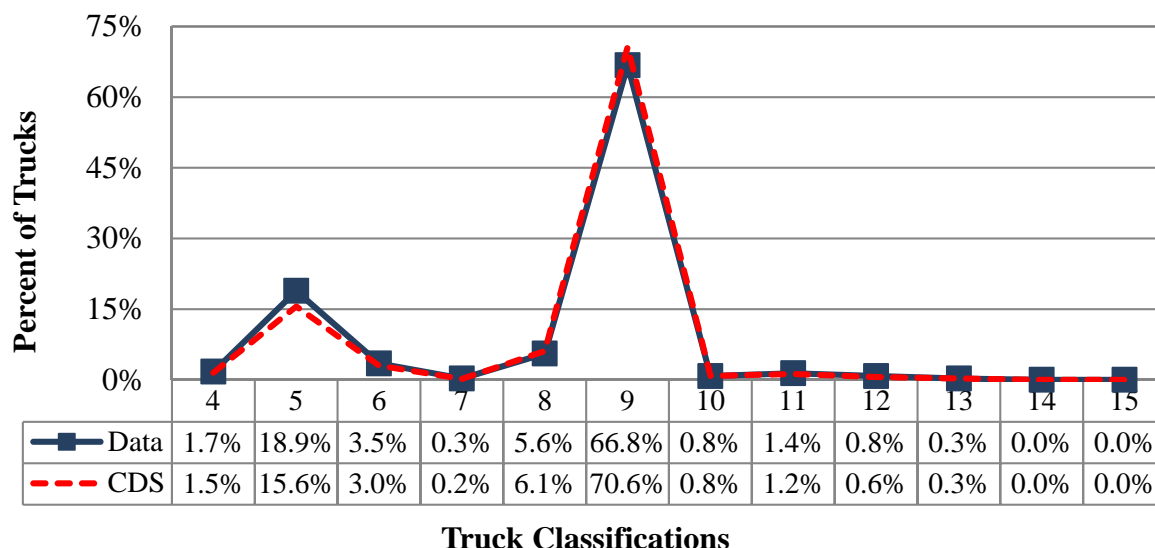
Table 2-2 provides a monthly breakdown of the available data for years 2006 through 2011.

**Table 2-2 – LTPP Data Availability by Month**

Year	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2006	31	28	31	30			18	24	23	31	29	27	10
2007	3	21		29	19	27	31	31	24	31	30		10
2008		29		30		30		31	30	31	30	29	8
2009	31	28	29	23	28		22	29	26	28	28	28	11
2010	29	23	27	29	24	22	28	30	30	30	30	31	12
2011	31	28	25	2	31	30	13	31	29	31	30	31	12
2012	31	29	31	30	30								5

## 2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions between the sample dataset from August 1, 2013 (Data) and the most recent comparison Data Set (CDS) from January 27, 2011.



**Figure 2-1 – Comparison of Truck Distribution**

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the two most frequent truck types crossing the WIM scale are Class 9 (66.8%) and Class 5 (18.9%) vehicles.

Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 0.0 percent of the vehicles at this site are unclassified.

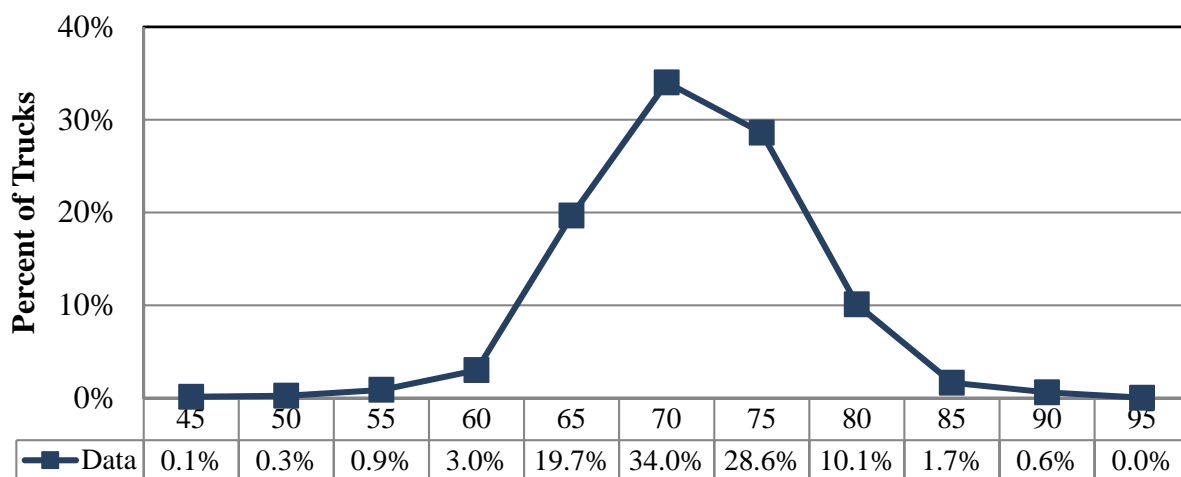
**Table 2-3 – Truck Distribution from W-Card**

Vehicle Classification	CDS		Data		Change
	Date				
	1/27/2011		8/1/2013		
4	320	1.5%	377	1.7%	0.2%
5	3268	15.6%	4105	18.9%	3.3%
6	630	3.0%	757	3.5%	0.5%
7	37	0.2%	62	0.3%	0.1%
8	1279	6.1%	1210	5.6%	-0.5%
9	14809	70.6%	14520	66.8%	-3.8%
10	176	0.8%	173	0.8%	0.0%
11	260	1.2%	300	1.4%	0.1%
12	126	0.6%	171	0.8%	0.2%
13	58	0.3%	59	0.3%	0.0%
14	0	0.0%	0	0.0%	0.0%
15	0	0.0%	0	0.0%	0.0%

From the table it can be seen that the percentage of Class 9 vehicles has decreased by 3.8 percent from January 2011 and August 2013. Changes in the percentage of heavier trucks may be attributed to natural and seasonal variations in truck distributions and changes in goods movement during current economic cycle. During the same time period, the percentage of Class 5 trucks increased by 3.3 percent. These differences may be attributed to changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

## 2.3 Speed Data Analysis

The traffic data received from the Texas DOT was analyzed to determine the expected truck speed distributions. This will provide a basis for determining the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.



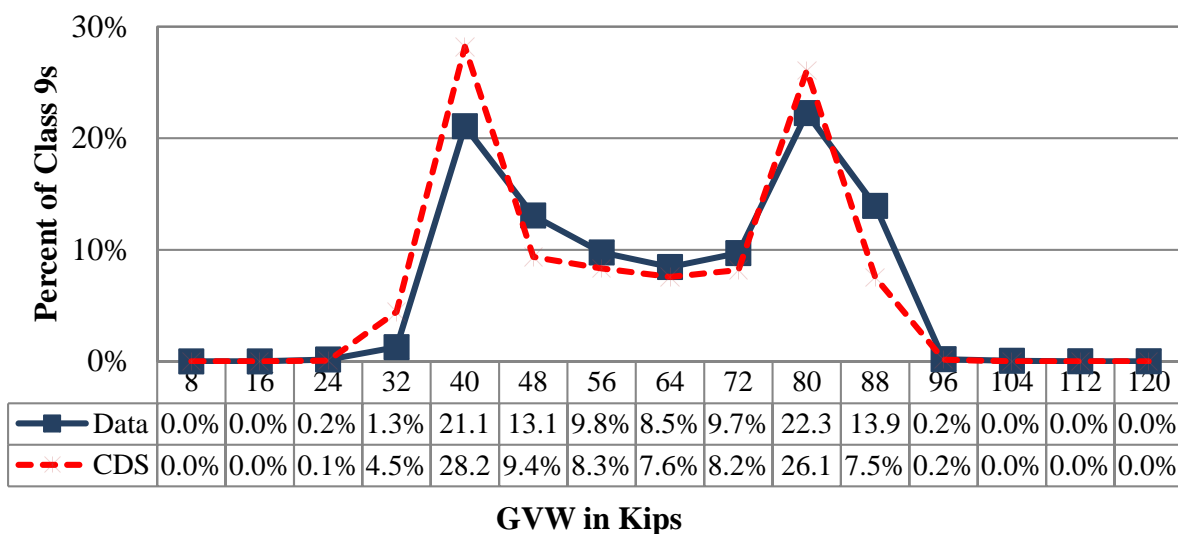
**Figure 2-2 – Truck Speed Distribution – 1-Aug-13**

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 65 and 75 mph. The posted speed limit at this site is 75 mph and the 85<sup>th</sup> percentile speed for trucks at this site is 75 mph. The range of truck speeds for the validation are expected to be between 60 to 70 mph.

## 2.4 GVW Data Analysis

The traffic CDS data received from the Texas DOT was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from August 2013 and the Comparison Data Set from January 2011.

As shown in Figure 2-3, there is a downward shift for the unloaded and loaded peaks between the January 2011 Comparison Data Set (CDS) and the August 2013 two-week sample W-card dataset (Data). The results indicate that there may be a change in pavement condition, or sensor deterioration, as well as natural variation in truck loads.



**Figure 2-3 – Comparison of Class 9 GVW Distribution**

Table 2-4 is provided to show the statistical comparison for Class 9 GVW between the Comparison Data Set and the current dataset.

**Table 2-4 – Class 9 GVW Distribution from W-Card**

GVW weight bins (kips)	CDS		Data		Change
	Date				
	1/27/2011		8/1/2013		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	11	0.1%	24	0.2%	0.1%
32	657	4.5%	184	1.3%	-3.2%
40	4160	28.2%	3038	21.1%	-7.1%
48	1382	9.4%	1884	13.1%	3.7%
56	1229	8.3%	1408	9.8%	1.4%
64	1118	7.6%	1220	8.5%	0.9%
72	1208	8.2%	1400	9.7%	1.5%
80	3846	26.1%	3208	22.3%	-3.8%
88	1111	7.5%	2010	13.9%	6.4%
96	24	0.2%	28	0.2%	0.0%
104	1	0.0%	7	0.0%	0.0%
112	0	0.0%	1	0.0%	0.0%
120	1	0.0%	1	0.0%	0.0%
Average =	56.3 kips		59.5 kips		3.2 kips

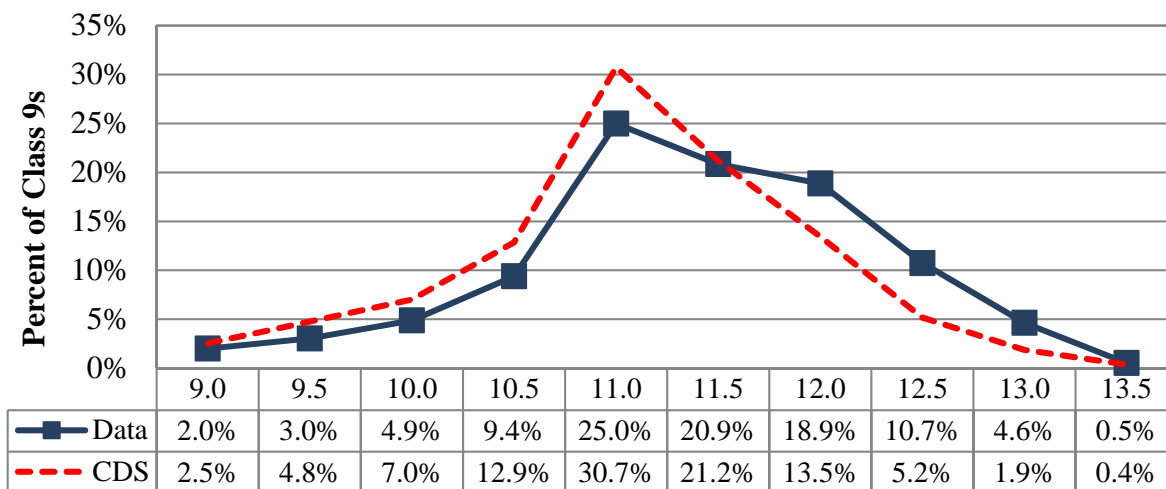


As shown in the table, the percentage of unloaded class 9 trucks in the 32 to 40 kips range decreased by 7.1 percent while the percentage of loaded class 9 trucks in the 72 to 80 kips range decreased by 3.8 percent. During this time period the percentage of overweight trucks increased by 6.54 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 5.3 percent, from 56.3 to 59.5 kips.

## 2.5 Class 9 Front Axle Weight Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average front axle weight. This will provide a basis for the evaluation of the quality of the data by comparing the average front axle weight from the current data sample set with the expected average front axle weight average from the Data Comparison Set.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from August 2013 and the Comparison Data Set from January 2011. The percentage of light axles (9.5 to 10.5 kips) decreased by approximately 5.6% and the percentage of heavy axles (11.5 to 12.5 kips) increased by approximately 10.71.0%, indicating possible positive bias (overestimation of loads) in front axle measurement.



Steering Axle Weight in Kips

**Figure 2-4 – Distribution of Class 9 Front Axle Weights**

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 11.0 and 12.0 kips. The percentage of trucks in this range has increased between the January 2011 Comparison Data Set (CDS) and the August 2013 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the January 2011 Comparison Data Set (CDS) and the August 2013 dataset (Data).

**Table 2-5 – Class 9 Front Axle Weight Distribution from W-Card**

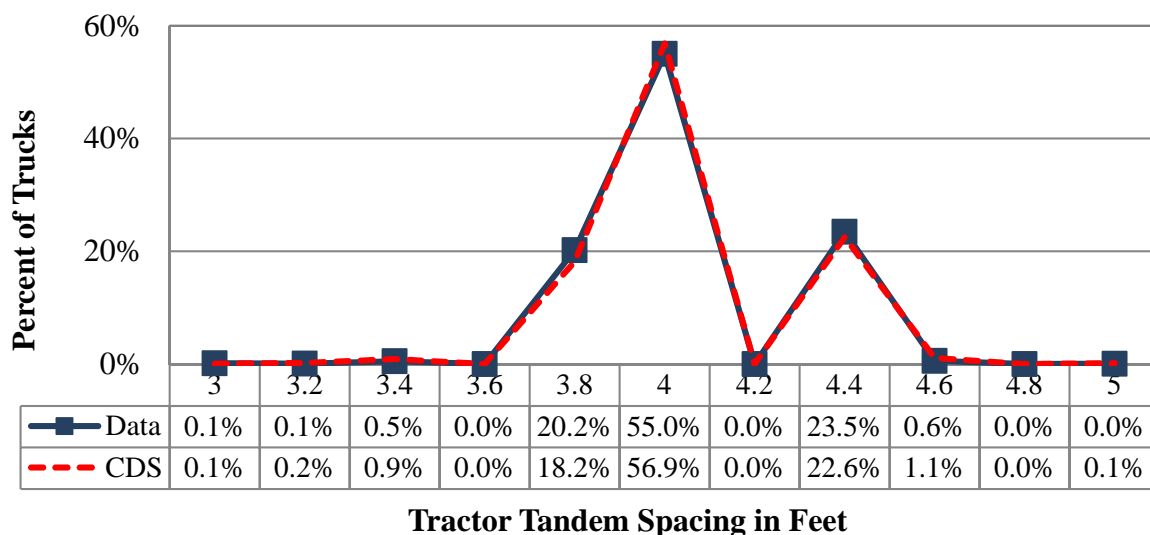
F/A weight bins (kips)	CDS		Data		Change
	Date				
	1/27/2011		8/1/2013		
9.0	373	2.5%	289	2.0%	-0.5%
9.5	701	4.8%	437	3.0%	-1.7%
10.0	1031	7.0%	701	4.9%	-2.1%
10.5	1890	12.9%	1349	9.4%	-3.5%
11.0	4516	30.7%	3586	25.0%	-5.8%
11.5	3114	21.2%	2993	20.9%	-0.3%
12.0	1976	13.5%	2709	18.9%	5.4%
12.5	760	5.2%	1542	10.7%	5.6%
13.0	275	1.9%	666	4.6%	2.8%
13.5	54	0.4%	78	0.5%	0.2%
Average =	10.9 kips		11.1 kips		0.2 kips

The table shows that the average front axle weight for Class 9 trucks has increased by 0.2 kips, or 1.8 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 11.1 kips.

## 2.6 Class 9 Tractor Tandem Spacing Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average tractor tandem spacing. This will provide a basis for the evaluation of the accuracy of the equipment distance and speed measurements by comparing the observed average tractor tandem spacing from the sample data (Data) with the expected average tractor tandem spacing from the comparison data set (CDS).

The class 9 tractor tandem spacing plot in Figure 2-5 is provided to indicate possible shifts in WIM system distance and speed measurement accuracies.



**Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing**

As seen in the figure, the Class 9 tractor tandem spacings for the January 2011 Comparison Data Set and the August 2013 Data are nearly identical.

Table 2-6 shows the Class 9 axle spacings between the second and third axles.

**Table 2-6 – Class 9 Axle 2 to 3 Spacing from W-Card**

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	1/27/2011		8/1/2013		
3.0	9	0.1%	20	0.1%	0.1%
3.2	28	0.2%	9	0.1%	-0.1%
3.4	131	0.9%	71	0.5%	-0.4%
3.6	0	0.0%	0	0.0%	0.0%
3.8	2685	18.2%	2912	20.2%	2.0%
4.0	8389	56.9%	7931	55.0%	-1.9%
4.2	0	0.0%	0	0.0%	0.0%
4.4	3326	22.6%	3384	23.5%	0.9%
4.6	160	1.1%	82	0.6%	-0.5%
4.8	0	0.0%	0	0.0%	0.0%
5.0	20	0.1%	7	0.0%	-0.1%
Average =	4.0 feet		4.0 feet		0.0 feet

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 3.8 and 4.4 feet. Based on the average Class 9 drive tandem spacing values from the per

vehicle records, the average tractor tandem spacing is 4.0, which is identical to the expected average of 4.0 from the CDS per vehicle records. Further axle spacing analyses are performed during the validation and post-validation analysis.

## **2.7 Data Analysis Summary**

Historical data analysis involved the comparison of the most recent Comparison Data Set (January 2011) based on the last calibration with the most recent two-week WIM data sample from the site (August 2013). Comparison of vehicle class distribution data indicates a 3.8 percent decrease in the percentage of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 1.8 percent and average Class 9 GVW has increased by 5.3 percent for the August 2013 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical to the expected average of 4.0 feet.

### **3 WIM Equipment Discussion**

From a comparison between the report of the most recent validation of this equipment on January 25, 2011 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

#### **3.1 Description**

This site was installed on February, 2005 by Texas DOT. It is instrumented with bending plate weighing sensors and an IRD DAW WIM Controller. Texas DOT personnel perform routine equipment maintenance and data quality checks of the WIM data.

#### **3.2 Physical Inspection**

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented after Section 9.

#### **3.3 Electronic and Electrical Testing**

Electronic and electrical checks of all system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were performed. All values for the WIM sensors and inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

#### **3.4 Equipment Troubleshooting and Diagnostics**

During the validation, it was noted that the WIM system was providing a wide range of overall length errors for the test trucks. It was also noted during the speed and classification study that two vehicles traveling close together were being combined into one vehicle by the system. This would result in a Class 15 (unclassified) vehicle. An investigation conducted with the Texas DOT personnel on site determined that the loop sensitivity had been set to the highest setting in order to capture trucks with low trailer mass, such as logging trucks. This setting appeared to be the cause of the vehicle length error spread and the class 15 reports. The TXDOT person on site was not authorized to make any changes to the WIM system loop settings and so the current setting was left in place.

#### **3.5 Equipment Maintenance Recommendations**

It is recommended that the loop sensitivity setting be further investigated and adjustments made to try to reduce the number of Class 15 reports and to decrease the spread in overall length measurement error. No other unscheduled equipment maintenance actions are recommended.

## 4 Pavement Discussion

### 4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, a transition from asphalt to concrete pavement was noted 345 feet prior to the WIM scales.

### 4.2 LTPP Pavement Profile Data Analysis

The IRI data files are processed using the WIM Smoothness Index software. The indices produced by the software provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment. The recommended thresholds for WIM Site pavement smoothness are provided in Table 4-1.

**Table 4-1 – Recommended WIM Smoothness Index Thresholds**

Index	Lower Threshold (m/km)	Upper Threshold (m/km)
Long Range Index (LRI)	0.50	2.1
Short Range Index (SRI)	0.50	2.1
Peak LRI	0.50	2.1
Peak SRI	0.75	2.9

When all values are less than the lower threshold shown in Table 4-1, it is unlikely that pavement conditions will significantly influence sensor output. Values between the threshold values may or may not influence the accuracy of the sensor output and values above the upper threshold would lead to sensor output that would preclude achieving the research quality loading data.

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 5 center profiler runs are presented in Table 4-2.

**Table 4-2 – WIM Index Values**

Profiler Passes			Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Avg
Left	LWP	LRI (m/km)	0.876	0.889	0.889			0.885
		SRI (m/km)	1.028	0.791	0.996			0.938
		Peak LRI (m/km)	0.876	0.896	0.899			0.890
		Peak SRI (m/km)	1.129	0.956	0.996			1.027
	RWP	LRI (m/km)	0.927	0.795	0.888			0.870
		SRI (m/km)	1.057	1.080	1.146			1.094
		Peak LRI (m/km)	0.980	0.890	0.996			0.955
		Peak SRI (m/km)	1.099	1.179	1.348			1.209
Center	LWP	LRI (m/km)	0.755	0.860	0.819	0.782	0.737	0.791
		SRI (m/km)	1.057	0.824	0.743	1.071	0.816	0.902
		Peak LRI (m/km)	0.850	0.861	0.864	0.861	1.000	0.887
		Peak SRI (m/km)	1.074	1.153	1.093	1.175	0.887	1.076
	RWP	LRI (m/km)	0.920	0.920	0.980	1.057	1.219	1.019
		SRI (m/km)	1.010	1.055	1.027	1.333	1.238	1.133
		Peak LRI (m/km)	0.964	0.924	0.980	1.062	1.224	1.031
		Peak SRI (m/km)	1.268	1.129	1.097	1.382	<b>2.926</b>	1.560
Right	LWP	LRI (m/km)	0.959	0.945	1.131			1.012
		SRI (m/km)	0.705	1.252	1.528			1.162
		Peak LRI (m/km)	1.034	0.989	1.146			1.056
		Peak SRI (m/km)	0.834	1.567	1.598			1.333
	RWP	LRI (m/km)	0.972	1.190	1.331			1.164
		SRI (m/km)	0.836	<b>2.103</b>	1.455			1.465
		Peak LRI (m/km)	1.015	1.206	1.331			1.184
		Peak SRI (m/km)	1.015	2.222	1.527			1.588

From Table 4-2 it can be seen that most of the indices computed from the profiles are between the upper and lower threshold values, with the remaining values over the upper threshold. Indices that are below the lower thresholds are shown in italics and indices above the upper thresholds are shown in bold. The highest values, on average, are the Peak SRI values in the right wheel path of the right shift passes (shown in bold and italics).

### 4.3 Profile and Vehicle Interaction

Profile data was collected on March 28, 2012 by the Southern Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, beginning 900 feet prior to WIM scales and ending 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the

left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 1000 foot WIM section and the 400 foot approach area is 394 in/mi and is located approximately 345 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. Truck bouncing was noted, however, the adverse dynamics appeared to diminish prior to the trucks crossing the WIM scale area.

Additionally, a visual observation of the trucks as they approach, traverse and leave the sensor area did not indicate any visible motion of the trucks that would affect the performance of the WIM scales. Trucks appear to track down the center of the lane.

#### **4.4 Recommended Pavement Remediation**

No pavement remediation is recommended.



## 5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the pre-validation, the calibration, and the post-validation test truck runs, as well as information resulting from the classification and speed studies. All analyses of test truck data and information on necessary equipment adjustments are provided.

### 5.1 Pre-Validation

The first set of test runs provides a general overview of system performance prior to any calibration adjustments for the given environmental, vehicle speed and other conditions.

The 40 pre-validation test truck runs were conducted on August 14, 2013, beginning at approximately 8:35 AM and continuing until 2:07 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 9 truck, loaded with crane counterweights, and equipped with air suspension on the tractor and trailer tandems, with standard tandem spacing on the tractor and trailer.

The test trucks were weighed prior to the pre-validation and were re-weighed at the conclusion of the pre-validation. The average test truck weights and measurements are provided in Table 5-1.

**Table 5-1 – Pre-Validation Test Truck Weights and Measurements**

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.6	10.5	16.5	16.5	17.1	17.1	12.2	4.3	31.4	4.2	52.1	59.0
2	68.5	10.3	13.8	13.8	15.4	15.4	11.8	4.3	29.0	4.1	49.2	56.7

Test truck speeds varied by 14 mph, from 59 to 73 mph. The measured pre-validation pavement temperatures varied 41.3 degrees Fahrenheit, from 87.0 to 128.3. The sunny weather conditions provided the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

As shown in Table 5-2, the site met all LTPP requirements for loading measurement but did not meet the requirements for axle length or overall length measurement as a result of the pre-validation test truck runs.

**Table 5-2 – Pre-Validation Overall Results – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	$\pm 20$ percent	$0.3 \pm 16.6\%$	Pass
Tandem Axles	$\pm 15$ percent	$1.0 \pm 10.1\%$	Pass
GVW	$\pm 10$ percent	$0.1 \pm 6.9\%$	Pass
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.9 \pm 5.3$ ft	FAIL
Axle Length	$\pm 0.5$ ft [150mm]	$-0.3 \pm 0.6$ ft	FAIL

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was  $1.2 \pm 3.0$  mph, which is greater than the  $\pm 1.0$  mph tolerance established by the LTPP Field Guide. Since the site is measuring axle spacing length with a mean error of  $-0.3 \pm 0.6$  feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is not set correctly and that the speeds being reported by the WIM equipment are not within acceptable ranges.

#### 5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 75 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3.

**Table 5-3 – Pre-Validation Results by Speed – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Low	Medium	High
		52.0 to 59.0 mph	59.1 to 67.0 mph	67.1 to 73.0 mph
Steering Axles	$\pm 20$ percent	$1.8 \pm 22.3\%$	$-2.0 \pm 7.0\%$	$1.7 \pm 22.0\%$
Tandem Axles	$\pm 15$ percent	$3.4 \pm 8.0\%$	$-0.7 \pm 10.4\%$	$-1.3 \pm 9.5\%$
GVW	$\pm 10$ percent	$2.9 \pm 5.2\%$	$-1.1 \pm 7.4\%$	$-1.0 \pm 6.1\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-1.6 \pm 6.6$ ft	$-0.1 \pm 4.0$ ft	$-1.2 \pm 6.3$ ft
Vehicle Speed	$\pm 1.0$ mph	$2.2 \pm 2.8$ mph	$-0.3 \pm 1.9$ mph	$-2.4 \pm 9.6$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$-0.3 \pm 0.8$ ft	$-0.2 \pm 0.5$ ft	$-0.3 \pm 0.6$ ft

From the table, it can be seen that the WIM equipment overestimates steering axle weights at low and high speeds and underestimates these weights at the medium speeds. The range in steering axle error appears to be much greater at the low and high speeds when compared with medium speeds. For GVW and tandem axles, the weights are overestimated at low speeds and underestimated at medium and high speeds. The range in GVW and tandem axle errors is similar for all of the speed groups.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following sections.

#### 5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment overestimated GVW at low speeds and underestimates GVW at the medium and high speeds. The range in error is similar for each of the three speed groups.

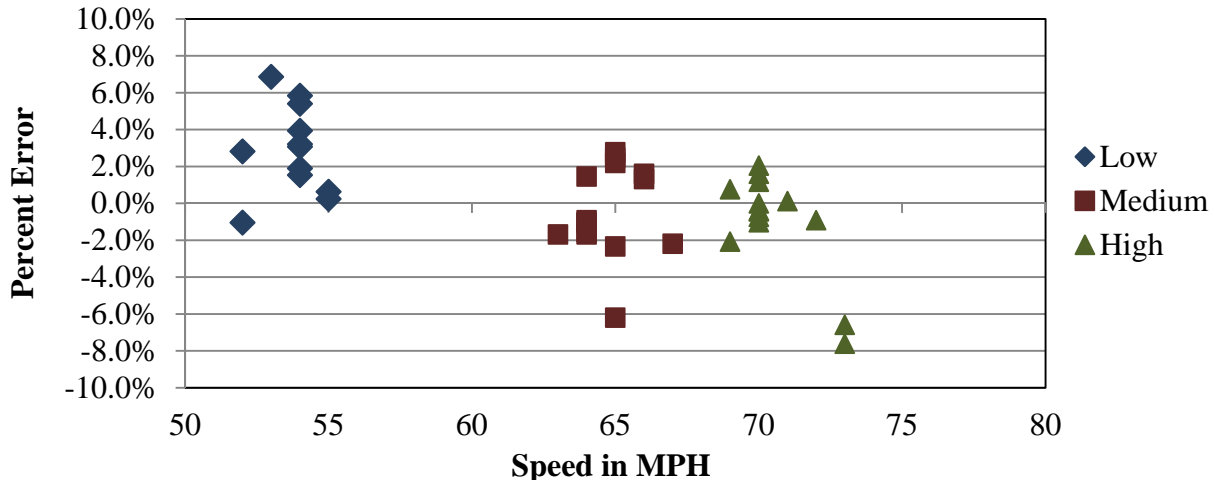


Figure 5-1 – Pre-Validation GVW Error by Speed – 15-Aug-13

#### 5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment estimates steering axle weights with similar bias at all speeds. The range in error is much higher at the lower and higher speeds when compared with the medium speeds.

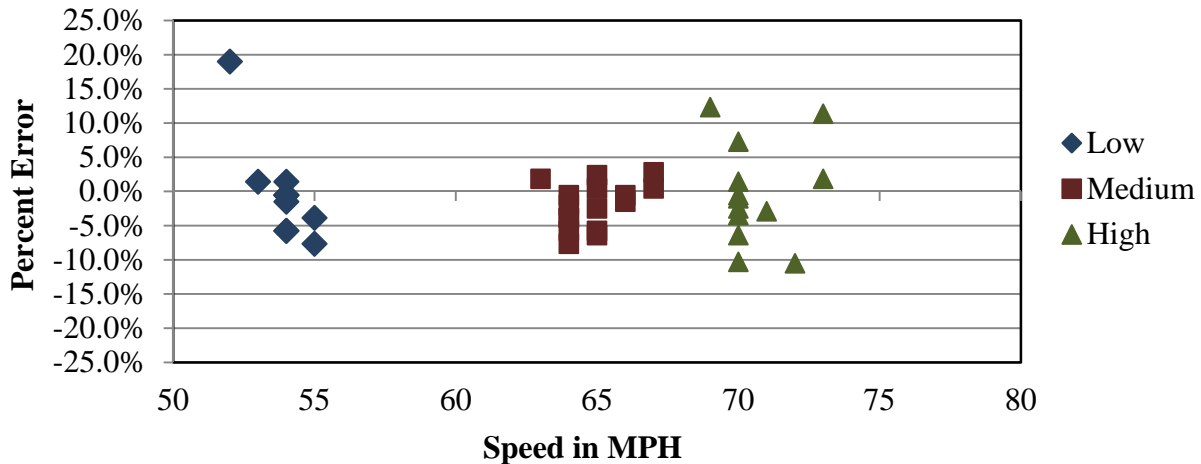
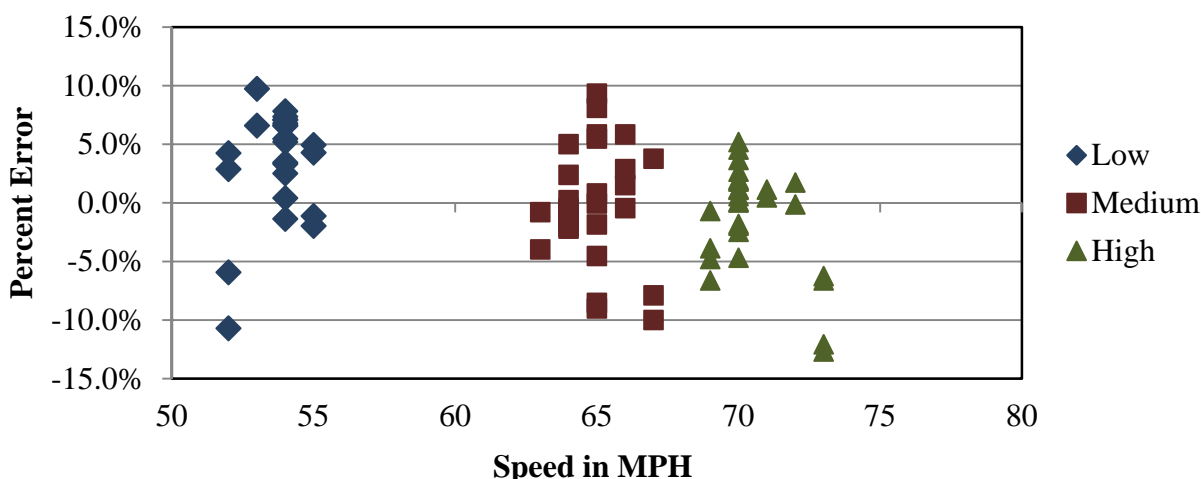


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 15-Aug-13

### 5.1.1.3 Tandem Axle Weight Errors by Speed

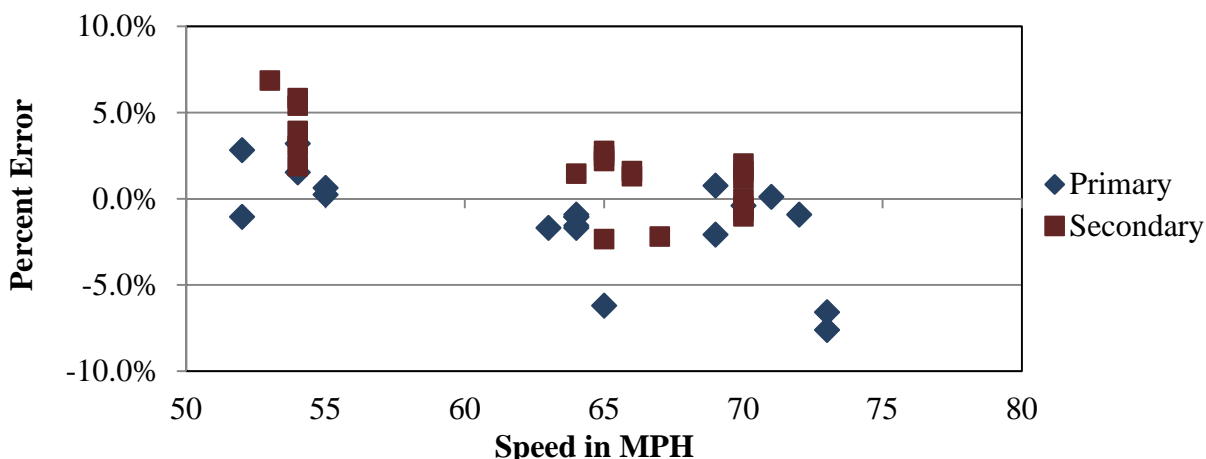
As shown in Figure 5-3, the equipment estimates tandem axle weights with similar accuracy at the medium and high speeds and overestimates weights at the lower speeds. The range in error is similar throughout the entire speed range.



**Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 15-Aug-13**

### 5.1.1.4 GVW Errors by Speed and Truck Type

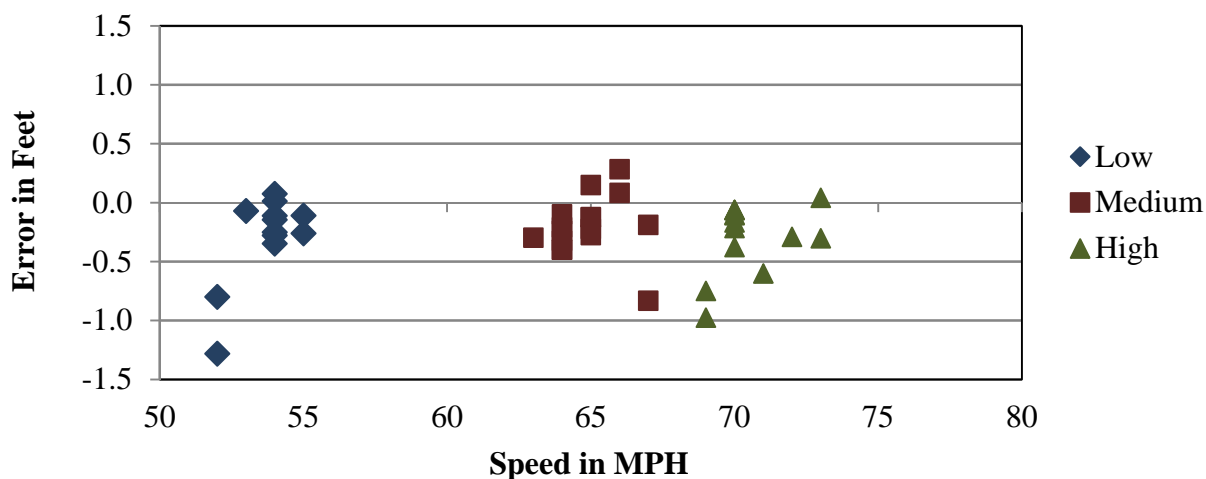
As shown in Figure 5-4, when the GVW error for each truck is analyzed as a function of speed, it can be seen that the WIM equipment overestimates GVW for the partially loaded (Secondary) truck by a greater degree than the loaded (Primary) truck at the low and medium speeds groups. At the medium and higher speeds, the equipment underestimates GVW for the Primary truck but not the secondary truck. The precision for secondary truck seems to be tighter than for the primary truck throughout the speed range.



**Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 15-Aug-13**

#### 5.1.1.5 Axle Length Errors by Speed

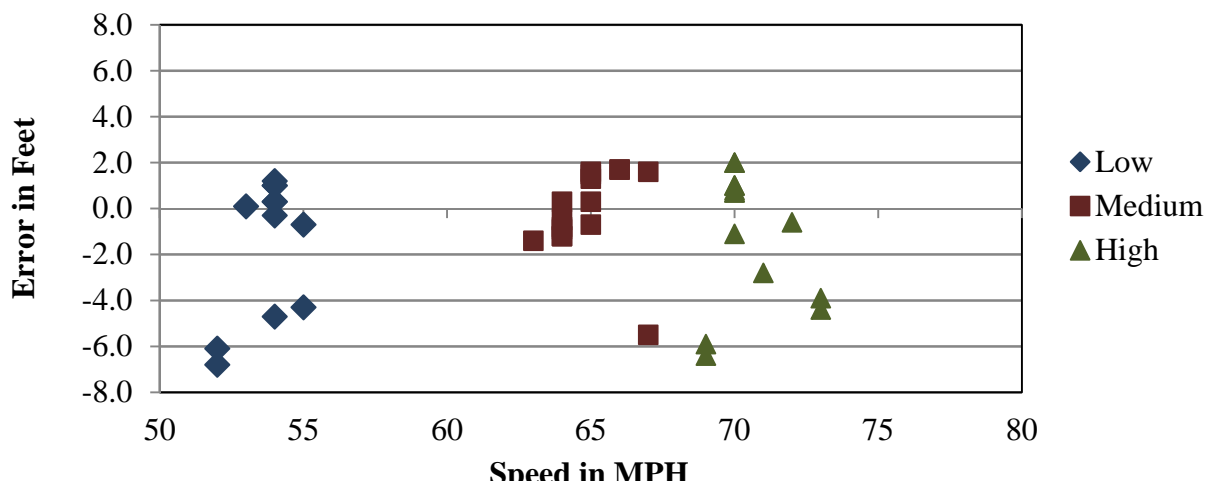
For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.3 feet to -1.3 feet. The range in error is greater at the lower speeds when compared with medium and high speeds. Distribution of errors is shown graphically in Figure 5-5.



**Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 15-Aug-13**

#### 5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment tends to underestimate overall vehicle length consistently over the entire range of speeds, with an error range of -6.0 to 2.0 feet. Distribution of errors is shown graphically in Figure 5-6.



**Figure 5-6 – Pre-Validation Overall Length Error by Speed – 15-Aug-13**

### 5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 34.0 degrees, from 99.0 to 133.0 degrees Fahrenheit. Although the desired 30 degree temperature range was met, considering the binominal distribution of pavement temperatures, the pre-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-4.

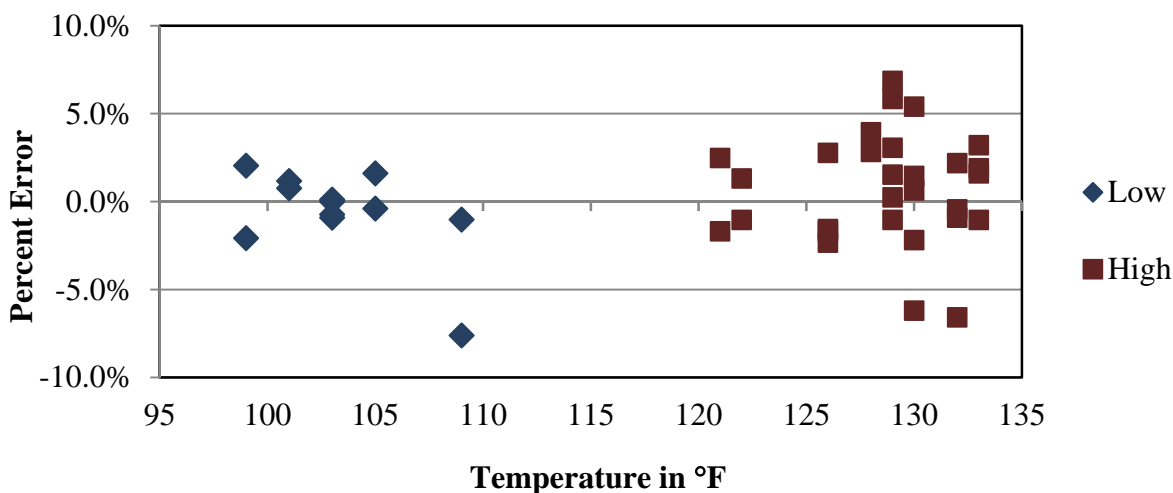
**Table 5-4 – Pre-Validation Results by Temperature – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Low	High
		99.0 to 115 degF	115.1 to 133.0 degF
Steering Axles	$\pm 20$ percent	$1.1 \pm 23.4\%$	$0.0 \pm 14.8\%$
Tandem Axles	$\pm 15$ percent	$-0.7 \pm 8.7\%$	$0.6 \pm 10.6\%$
GVW	$\pm 10$ percent	$-0.6 \pm 5.5\%$	$0.3 \pm 7.6\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-1.3 \pm 6.4$ ft	$-0.8 \pm 5.1$ ft
Vehicle Speed	$\pm 1.0$ mph	$-3.0 \pm 10.0$ mph	$0.8 \pm 3.3$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$-0.3 \pm 0.6$ ft	$-0.2 \pm 0.6$ ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle, and axle group weights.

#### 5.1.2.1 GVW Errors by Temperature

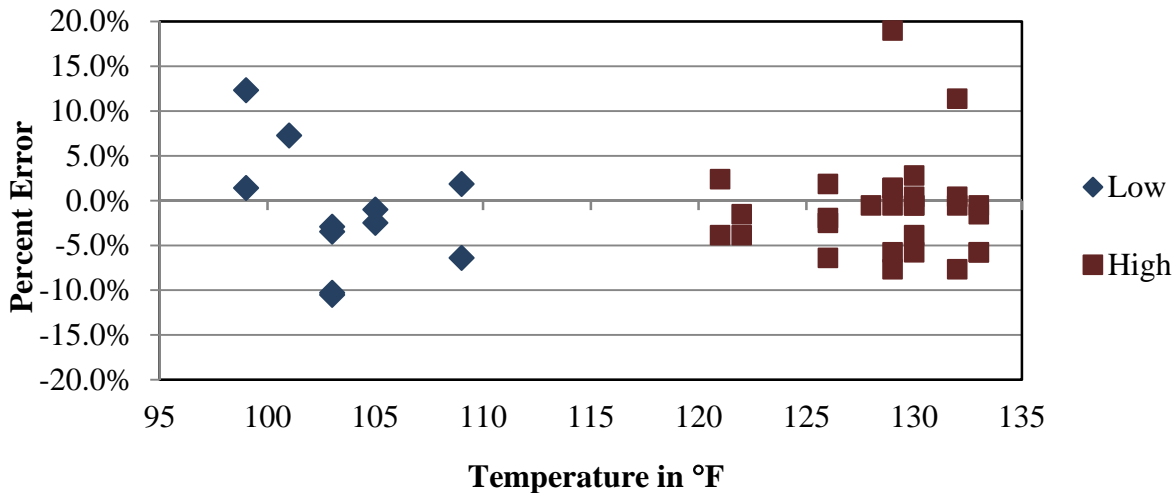
From Figure 5-7, it can be seen that no consistent bias is present in GVW estimates across the range of temperatures observed in the field. The range in error is greater for the higher temperature group when compared with the lower temperature group.



**Figure 5-7 – Pre-Validation GVW Errors by Temperature – 15-Aug-13**

#### 5.1.2.2 Steering Axle Weight Errors by Temperature

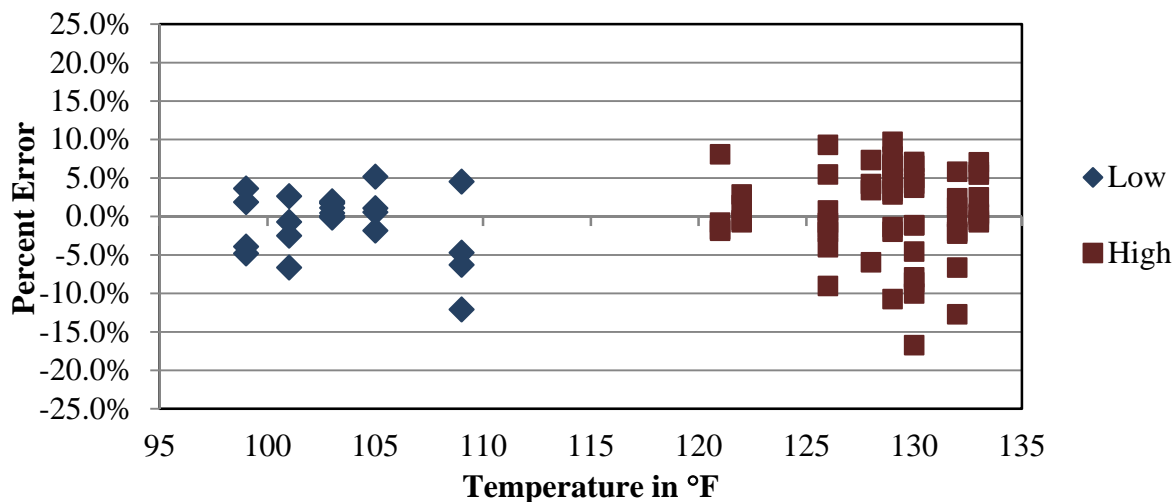
Figure 5-8 illustrates that for steering axles, the WIM equipment estimates weights similarly across the range of temperatures.



**Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 15-Aug-13**

#### 5.1.2.3 Tandem Axle Weight Errors by Temperature

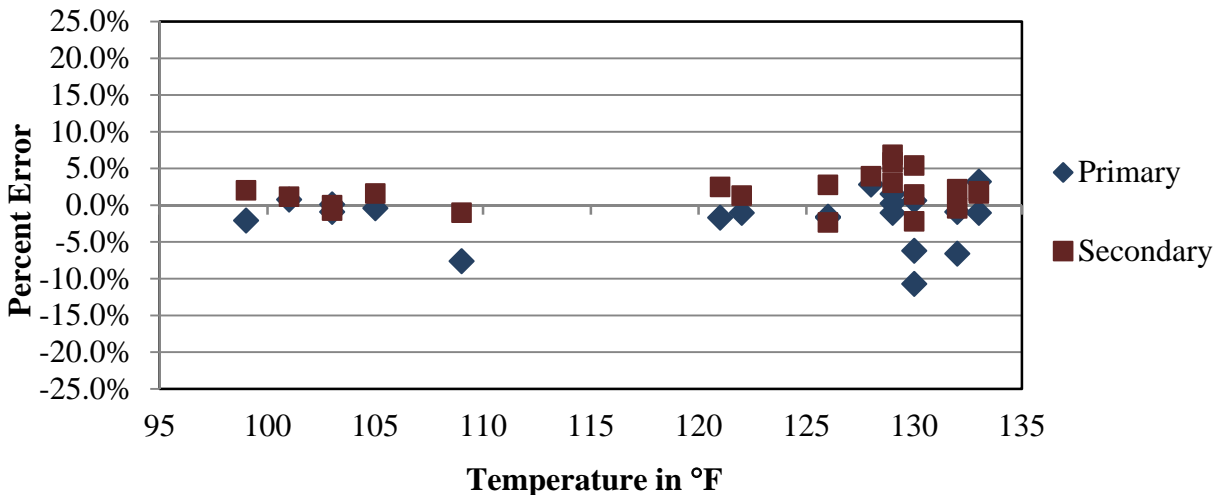
As shown in Figure 5-9, no consistent bias in tandem axle weights estimates is present across the range of temperatures. The range in error is greater for the higher temperature group when compared with the lower temperature group.



**Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 15-Aug-13**

#### 5.1.2.4 GVW Errors by Temperature and Truck Type

From Figure 5-10, it can be seen that the WIM equipment generally underestimates GVW for the heavily loaded (Primary) truck and the generally overestimates GVW for the partially loaded (Secondary) truck. For both trucks, the range of errors appears to be greater for the higher temperature group.



**Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 15-Aug-13**

#### 5.1.3 Classification and Speed Evaluation

The pre-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the pre-validation classification study at this site, a manual sample of 110 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. Based on the vehicles observed during the pre-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is also 0.0%.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. Based on the manually collected sample of the 110 trucks, 0.0 percent of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTPP SPS WIM sites.



For speed, the mean error for WIM equipment speed measurement was 1.2 mph; the range of errors was 2.6 mph.

## 5.2 Calibration

The WIM equipment required one calibration iteration between the pre- and post-validations. Information regarding the basis for changing equipment compensation factors, supporting data for the changes, and the resulting WIM accuracies from the calibrations are provided in this section.

The operating system weight compensation parameters that were in place prior to the pre-validation are shown in Table 5-5.

**Table 5-5 – Initial System Parameters – 15-Aug-13**

Speed Points		
SP1	10	825
SP2	55	800
SP3	65	805
Other		
Overall -		2600
Front Axle -		1000
Left -		1000
Right -		1000
Distance -		185
Loop Width -		246

### 5.2.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of 0.1% and errors of 2.9%, -1.1%, and -1.0% at the 60, 65 and 70 mph speed points respectively. To compensate for these errors, the changes in Table 5-6 were made to the compensation factors.

**Table 5-6 – Calibration 1 Equipment Factor Changes – 15-Aug-13**

Speed Points		Old	New
SP1	55	825	803
SP2	65	800	778
SP3	75	805	814
<b>Other</b>			
Overall -		2600	2600
Front Axle -		1000	998
Left -		1000	1000
Right -		1000	1000
Distance -		185	185
Loop Width -		246	246

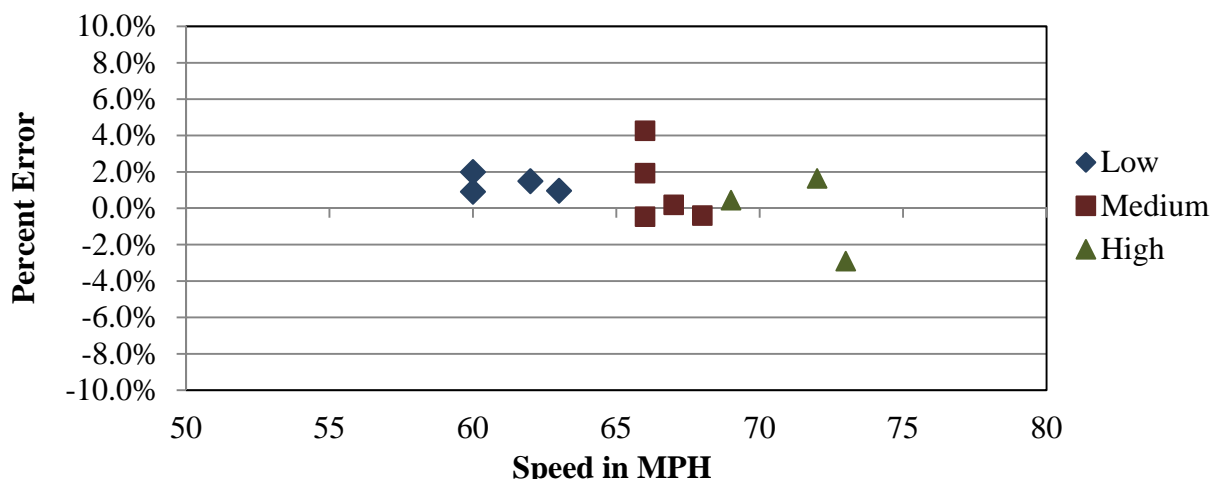
### 5.2.2 Calibration Results

The results of the 12 calibration verification runs are provided in Table 5-7 and Figure 5-11. As can be seen in the table, the range in error for GVW was reduced from 6.9% to 3.8% as a result of the calibration. The overall length again failed due to the wide range of error. This may be attributed to the loop sensitivity setting discussed in Section 3.4.

**Table 5-7 – Calibration Results – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	$\pm 20$ percent	$-2.4 \pm 5.3\%$	Pass
Tandem Axles	$\pm 15$ percent	$0.8 \pm 6.1\%$	Pass
GVW	$\pm 10$ percent	$0.8 \pm 3.8\%$	Pass
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.2 \pm 3.9$ ft	FAIL
Axle Length	$\pm 0.5$ ft [150mm]	$-0.2 \pm 0.4$ ft	Pass

Figure 5-11 shows that the WIM equipment is estimating GVW with similar accuracy at all speeds. There was one outlier at the higher speeds.



**Figure 5-11 – Calibration GVW Error by Speed – 15-Aug-13**

Based on the results of the calibration, where the range in all weight estimate errors decreased, a second calibration was not considered to be necessary. It was determined that the accuracy of the overall length measurement could not be improved through further calibration. The 12 calibration runs were combined with 28 additional post-validation runs to complete the WIM system validation.

### 5.3 Post-Validation

The 40 post-validation test truck runs were conducted on August 15, 2013, beginning at approximately 8:35 AM and continuing until 2:07 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with concrete blocks, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.
- A Class 9 truck, loaded with crane counter-weights, and equipped with air suspension on the tractor and trailer, with standard tandem spacing on the tractor and trailer.

The test trucks were weighed prior to the post-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-8.

**Table 5-8 – Post-Validation Test Truck Measurements**

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	77.7	10.5	16.5	16.5	17.1	17.1	12.2	4.3	31.4	4.2	52.1	59.0
2	68.6	10.3	13.8	13.8	15.4	15.4	11.8	4.3	29.0	4.1	49.2	56.7

Test truck speeds varied by 14 mph, from 59 to 73 mph. The measured post-validation pavement temperatures varied 41.3 degrees Fahrenheit, from 87.0 to 128.3. The sunny weather conditions provided the desired minimum 30 degree temperature range. Table 5-9 is a summary of post validation results.

**Table 5-9 – Post-Validation Overall Results – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	$\pm 20$ percent	$-2.5 \pm 7.0\%$	Pass
Tandem Axles	$\pm 15$ percent	$0.5 \pm 6.4\%$	Pass
GVW	$\pm 10$ percent	$0.0 \pm 3.6\%$	Pass
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.3 \pm 3.4$ ft	FAIL
Axle Length	$\pm 0.5$ ft [150mm]	$-0.1 \pm 0.3$ ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was  $1.2 \pm 3.0$  mph, which is greater than the  $\pm 1.0$  mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of -0.1 feet, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

### 5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 75 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-10.

**Table 5-10 – Post-Validation Results by Speed – 15-Aug-13**

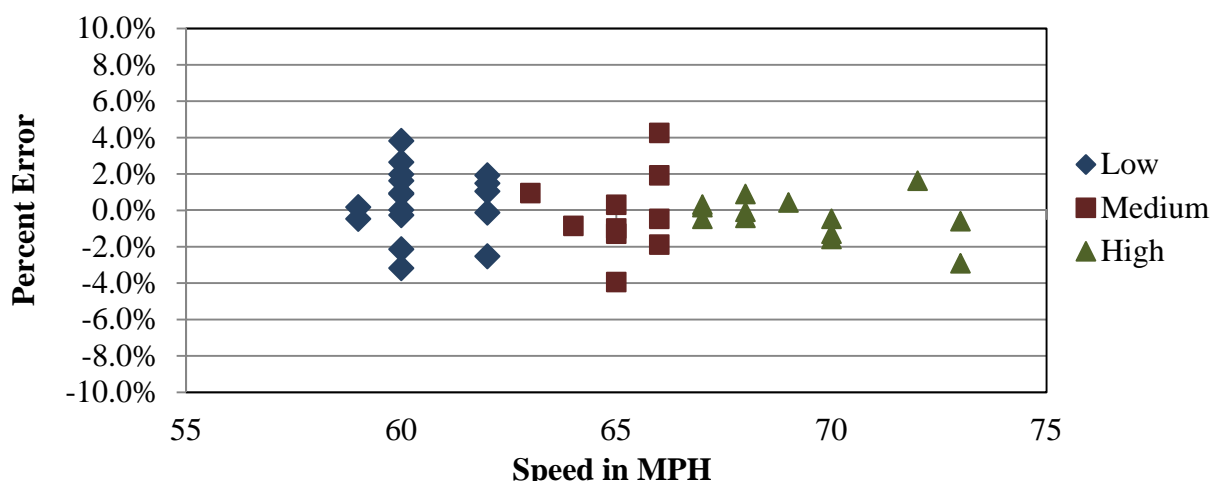
Parameter	95% Confidence Limit of Error	Low	Medium	High
		59.0 to 62.0 mph	62.1 to 66.0 mph	66.1 to 73.0 mph
Steering Axles	$\pm 20$ percent	$-1.7 \pm 7.7\%$	$-3.3 \pm 8.3\%$	$-2.9 \pm 6.7\%$
Tandem Axles	$\pm 15$ percent	$1.0 \pm 6.7\%$	$0.5 \pm 8.9\%$	$0.1 \pm 4.5\%$
GVW	$\pm 10$ percent	$0.5 \pm 3.9\%$	$-0.2 \pm 5.1\%$	$-0.3 \pm 2.5\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.3 \pm 4.4$ ft	$-0.2 \pm 1.5$ ft	$-0.2 \pm 3.8$ ft
Vehicle Speed	$\pm 1.0$ mph	$0.9 \pm 3.5$ mph	$1.2 \pm 2.8$ mph	$1.6 \pm 3.0$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$-0.1 \pm 0.3$ ft	$-0.2 \pm 0.3$ ft	$-0.1 \pm 0.3$ ft

From the table, it can be seen that the WIM equipment precision for all post-validation parameters is improved from the pre-validation runs shown in Table 5-2. The range in error appears to be greater for medium speed groups when compared with the low and high speeds groups. The equipment underestimates steering axle weights at all speeds, but measures GVW and tandem axle weights accurately across the entire speed range. There does not appear to be a relationship between weight estimates and speed after the speed compensation factors were reset.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following paragraphs.

#### 5.3.1.1 GVW Errors by Speed

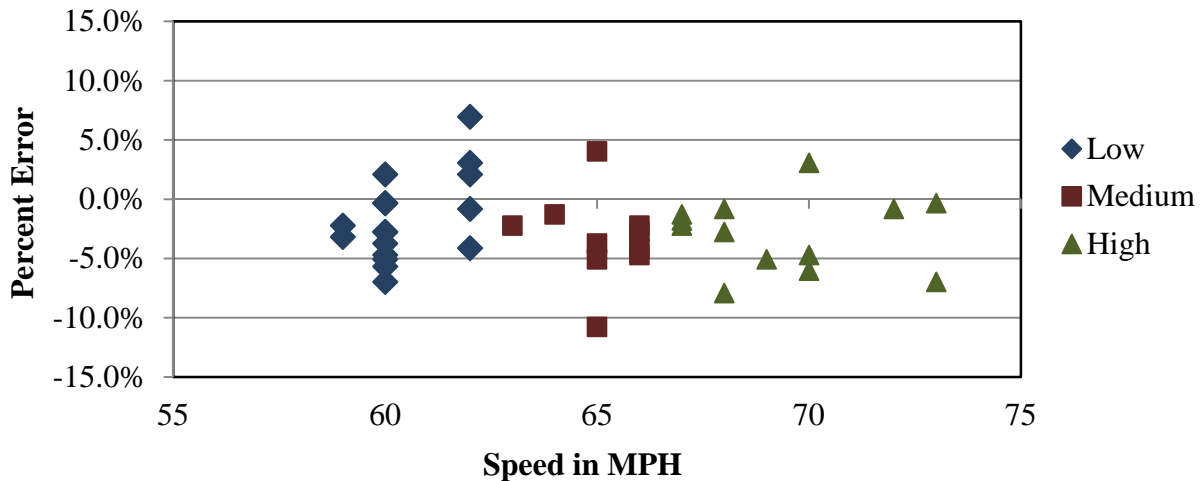
As shown in Figure 5-12, the equipment estimated GVW with similar accuracy at all speeds. The range in error is greater at the low and medium speeds when compared with higher speeds.



**Figure 5-12 – Post-Validation GVW Errors by Speed – 15-Aug-13**

### 5.3.1.2 Steering Axle Weight Errors by Speed

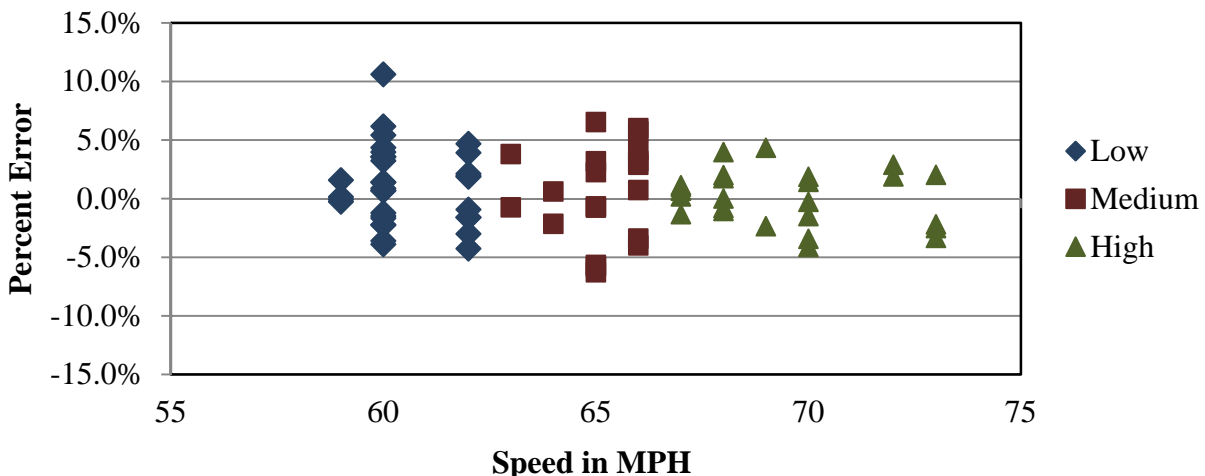
As shown in Figure 5-13, the equipment underestimated steering axle weights with higher bias at medium and higher speeds. The range in error is greater at the lower and medium speeds when compared with higher speeds. There does not appear to be a significant correlation between speed and steering axle weight estimates at this site.



**Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 15-Aug-13**

### 5.3.1.3 Tandem Axle Weight Errors by Speed

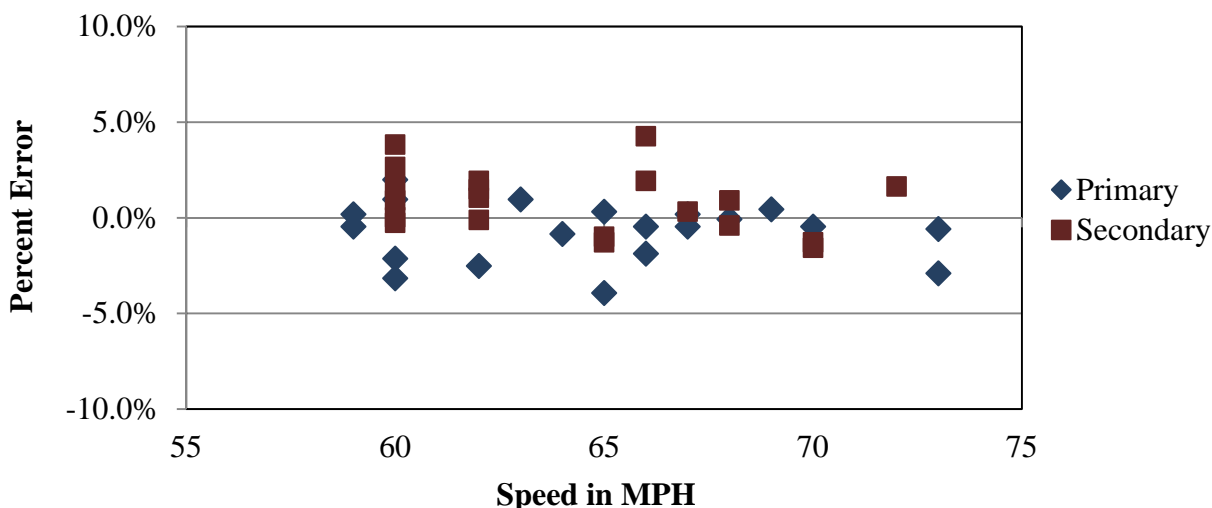
As shown in Figure 5-14, the equipment estimated tandem axle weights with similar accuracy at all speeds. The range in error is greater at the low and medium speeds when compared with the higher speeds.



**Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 15-Aug-13**

#### 5.3.1.4 GVW Errors by Speed and Truck Type

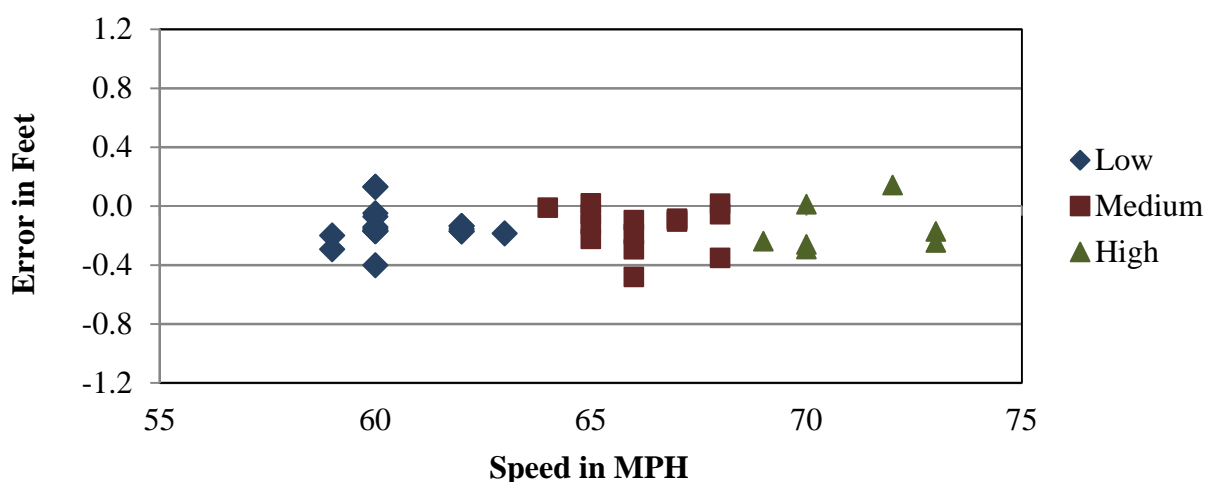
It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment generally underestimates GVW for the heavily loaded (Primary) truck and overestimates GVW for the partially loaded (Secondary) truck. The range in error for each of the trucks appears to be similar for each of the speed groups.



**Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 15-Aug-13**

#### 5.3.1.5 Axle Length Errors by Speed

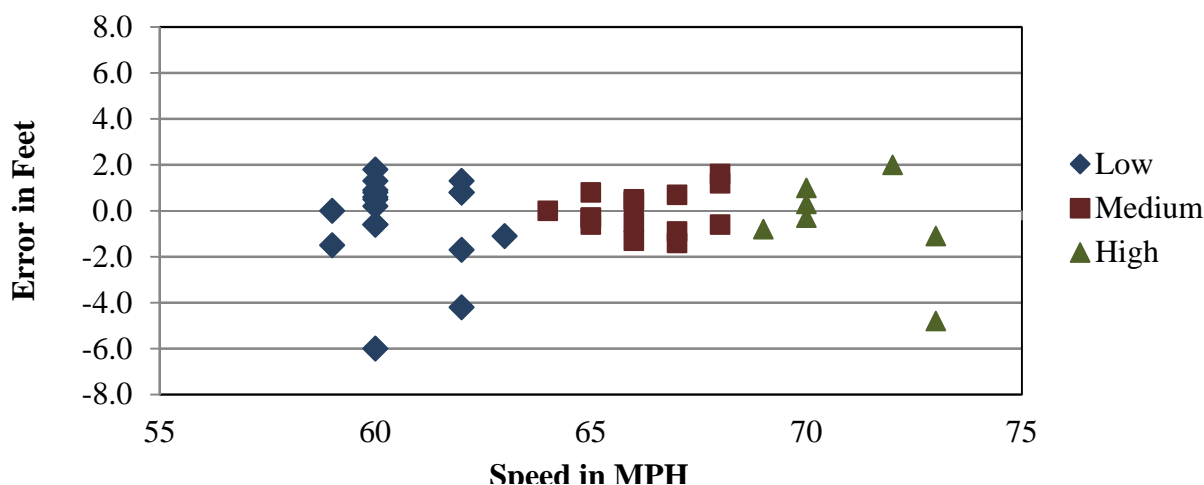
For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from -0.5 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-16.



**Figure 5-16 – Post-Validation Axle Length Error by Speed – 15-Aug-13**

### 5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length inconsistently over the range of speeds, with errors ranging from -6.0 to 2.0 feet. This may be attributed to the loop sensitivity setting as discussed in Section 3.4. Distribution of errors is shown graphically in Figure 5-17.



**Figure 5-17 – Post-Validation Overall Length Error by Speed – 15-Aug-13**

### 5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 41.3 degrees, from 87.0 to 128.3 degrees Fahrenheit. The post-validation test runs are reported under three temperature groups – low, medium and high, as shown in Table 5-11 below.

**Table 5-11 – Post-Validation Results by Temperature – 15-Aug-13**

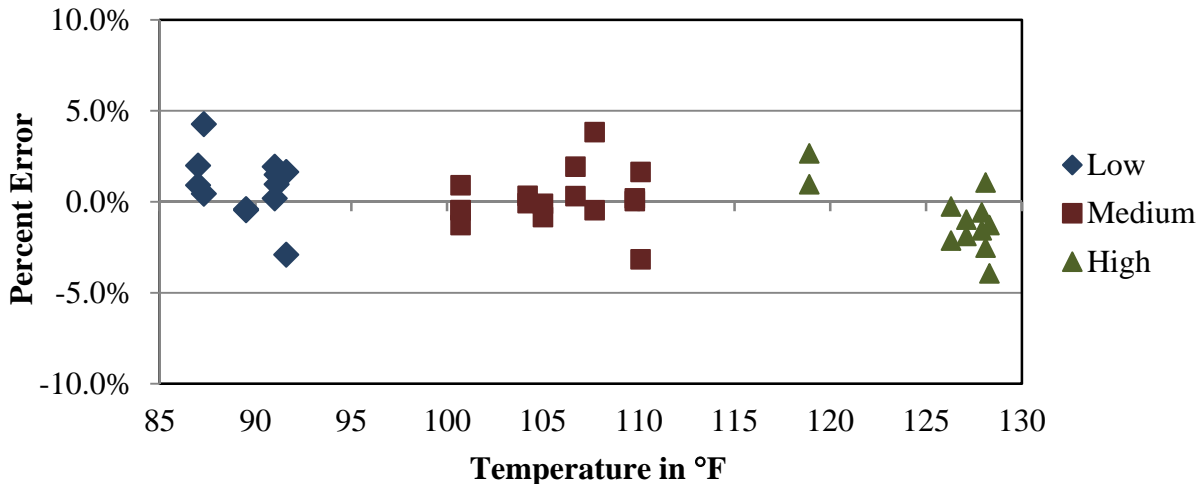
Parameter	95% Confidence Limit of Error	Low	Medium	High
		87.0 to 97 degF	97.1 to 115.0 degF	115.1 to 128.3 degF
Steering Axles	$\pm 20$ percent	$-2.4 \pm 5.3\%$	$-2.2 \pm 8.5\%$	$-2.9 \pm 8.5\%$
Tandem Axles	$\pm 15$ percent	$1.5 \pm 6.1\%$	$0.6 \pm 6.5\%$	$-0.4 \pm 7.9\%$
GVW	$\pm 10$ percent	$0.8 \pm 3.8\%$	$0.1 \pm 3.2\%$	$-0.9 \pm 3.9\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-0.2 \pm 3.9$ ft	$-0.3 \pm 3.9$ ft	$-0.3 \pm 3.3$ ft
Vehicle Speed	$\pm 1.0$ mph	$1.8 \pm 2.8$ mph	$1.3 \pm 3.8$ mph	$0.5 \pm 2.0$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$-0.2 \pm 0.4$ ft	$-0.1 \pm 0.3$ ft	$-0.1 \pm 0.2$ ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle weights, and axle group weights.



### 5.3.2.1 GVW Errors by Temperature

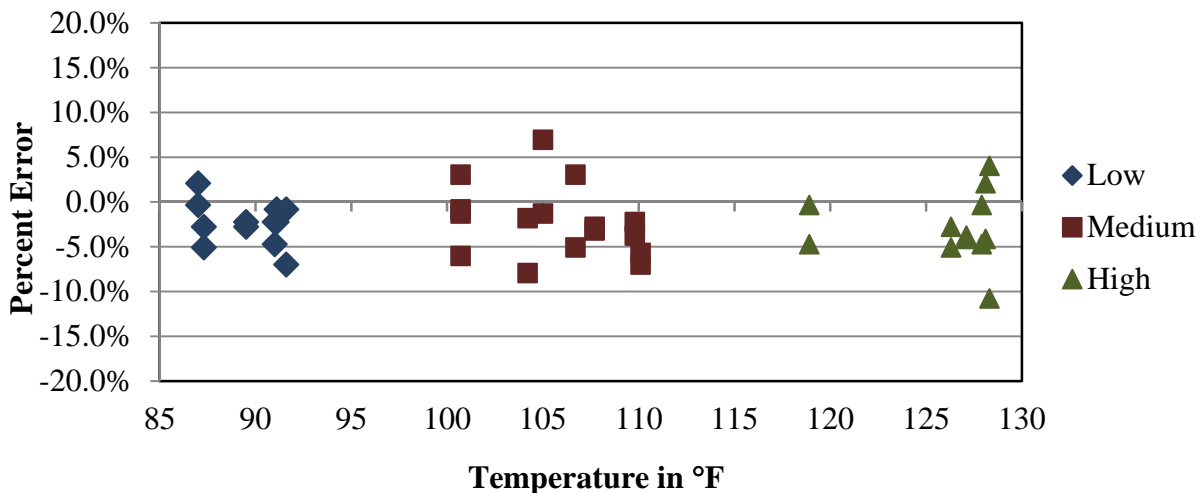
From Figure 5-18, it can be seen that the equipment appears to estimate GVW with similar accuracy across the range of temperatures observed in the field, with a slight underestimation of GVW at the higher temperatures. There does not appear to be a significant correlation between temperature and GVW estimates at this site.



**Figure 5-18 – Post-Validation GVW Errors by Temperature – 15-Aug-13**

### 5.3.2.2 Steering Axle Weight Errors by Temperature

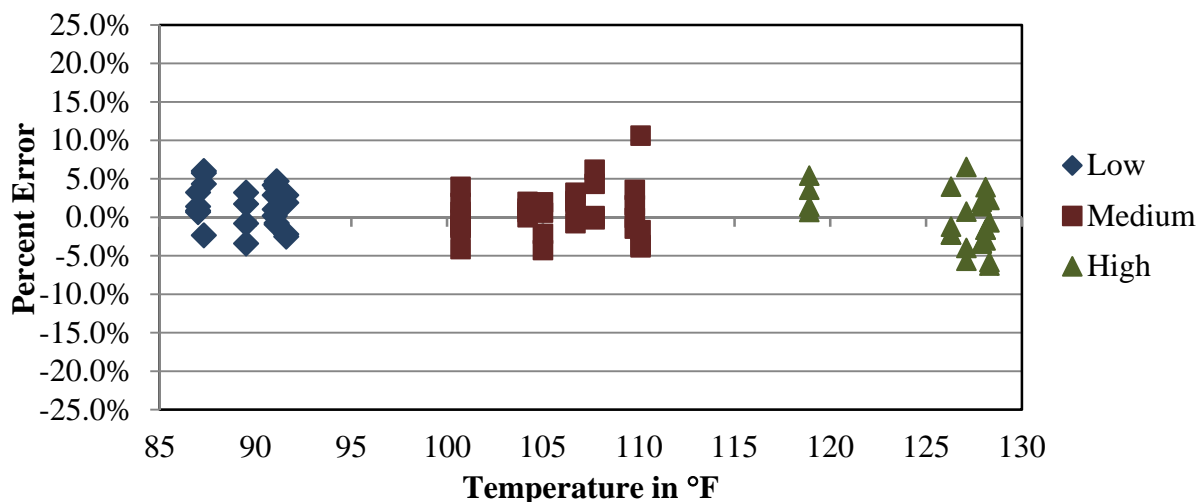
Figure 5-19 demonstrates that for steering axles, the WIM equipment appears to underestimate weights with similar bias across the range of temperatures observed in the field. The range in error is greater for the medium and high temperature groups when compared with the low temperature group.



**Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 15-Aug-13**

### 5.3.2.3 Tandem Axle Weight Errors by Temperature

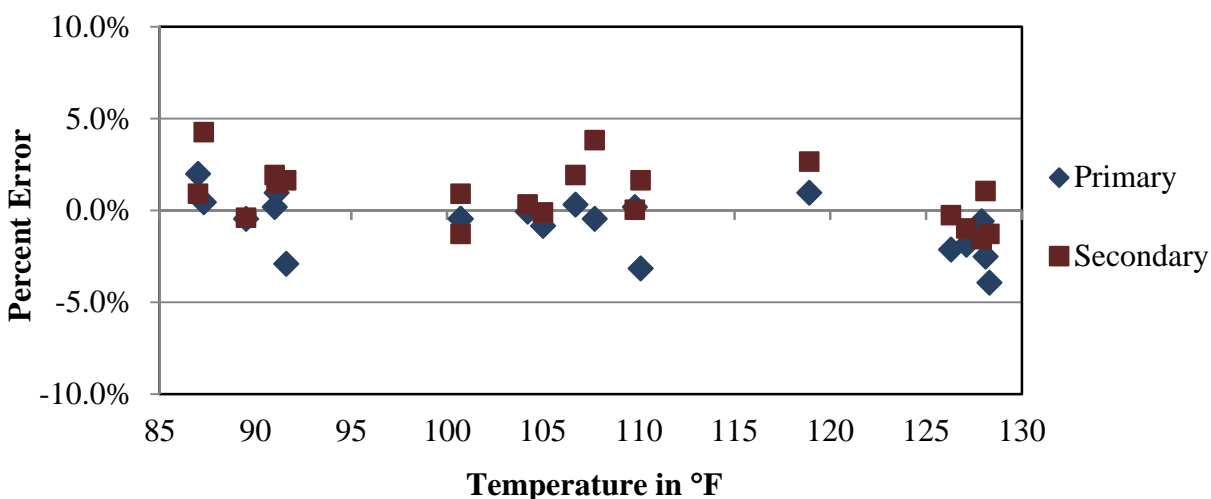
As shown in Figure 5-20, the WIM equipment appears to estimate tandem axle weights with similar accuracy across the range of temperatures observed in the field. The range in tandem axle errors is similar for the three temperature groups.



**Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 15-Aug-13**

### 5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, it appears that GVW for the Primary truck is slightly underestimated and GVW for the Secondary truck slightly overestimated. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures.



**Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 15-Aug-13**

### 5.3.3 Classification and Speed Evaluation

The post-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the post-validation classification study at this site, a manual sample of 110 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field.

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. The misclassifications by pair are provided in Table 5-12. The table illustrates the breakdown of vehicles observed and identified by the equipment for the manual classification study. As shown in Table 5-12, one Class 3 vehicle was misclassified as a Class 5 vehicle, and one Class 3 was misclassified as a Class 8 vehicle. For Class 9s, one was identified as a Class 10 and three were not classified (Class 15) by the equipment.

**Table 5-12 – Post-Validation Misclassifications by Pair – 15-Aug-13**

	WIM													
		3	4	5	6	7	8	9	10	11	12	13	14	15
Observed	3	-		1			1							
	4		-											
	5			-										
	6				-									
	7					-								
	8						-							
	9							-	1					3
	10								-					
	11									-				
	12										-			
	13											-	-	

As shown in the table, a total of 7 vehicles, including 4 heavy trucks (6 – 13) were misclassified by the equipment. Three of the heavy trucks were unclassified. Based on the vehicles observed during the post-validation study, the misclassification percentage is 3.8% for heavy trucks (vehicle classes 6 – 13), which is greater than the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (3 – 15) is 5.4 percent. The causes for the misclassifications of heavy trucks was not investigated in the field.

The combined results of the misclassifications resulted in an undercount of two Class 3s and four Class 9s, and an overcount of one Class 5, one Class 8 and one Class 10 vehicle, as shown in

Table 5-13. The misclassified percentage represents the percentage of the misclassified vehicles in the manual sample. The entries in the table show the percentages of misclassified vehicles observed in the manual sample for each vehicle class. The last column shows the percentage of unclassified vehicles observed in the manual sample.

**Table 5-13 – Post-Validation Classification Study Results – 15-Aug-13**

Class	3	4	5	6	7	8	9	10	11	12	13
Observed Count	2	0	6	4	0	2	94	1	2	1	0
WIM Count	0	0	7	4	0	3	90	2	2	1	0
Observed Percent	1.8	0.0	5.4	3.6	0.0	1.8	83.9	0.9	1.8	0.9	0.0
WIM Percent	0.0	0.0	6.3	3.6	0.0	2.7	80.4	1.8	1.8	0.9	0.0
Misclassified Count	2	0	0	0	0	0	4	0	0	0	0
Misclassified Percent	100.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	3	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-14.

**Table 5-14 – Post-Validation Unclassified Trucks by Pair – 15-Aug-13**

Observed Class	Unclassified	Observed Class	Unclassified	Observed Class	Unclassified
3	0	7	0	11	0
4	0	8	0	12	0
5	0	9	3	13	0
6	0	10	0		

Based on the manually collected sample of the 110 trucks, 2.7 percent of the vehicles at this site were reported as unclassified during the study. This is not within the established criteria of 2.0% for LTTP SPS WIM sites.

For speed, the mean error for WIM equipment speed measurement was 1.0 mph; the range of errors was 2.1 mph.

#### 5.3.4 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-15.

**Table 5-15 – Final Factors**

<b>Speed Points</b>		
SP1	55	803
SP2	65	800
SP3	75	805
<b>Other</b>		
Overall -		2600
Front Axle -		1000
Left -		1000
Right -		1000
Distance -		185
Loop Width -		246

## 6 Post-Visit Data Analysis

A post-visit data analysis is conducted to further evaluate the validation truck data to determine if any relationships exist between WIM system weight and distance measurement error based on speed, temperature and/or truck type. Additionally, an analysis of the post-visit misclassifications noted during the post-validation classification and speed study is conducted to possibly determine the cause of each truck misclassification.

If necessary, a traffic data sample from the days immediately following the validation to the date of the report submission may be conducted to further investigate anomalies in the traffic data that may have resulted from the calibration of the system or any other changes to the WIM system

### 6.1 Regression Analysis

This section provides additional results for the analysis carried out to determine the influence of truck type, speed and pavement temperature on WIM measurement errors. Multivariable linear regression analysis was applied to WIM data collected during calibration procedures. The same calibration data analyzed and discussed previously was used for this analysis; however a more comprehensive statistical methodology was applied. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analysis provides additional insight on how factors like speed, temperature, and truck type may affect weight measurement errors for a specific WIM site. It is expected that multivariable analysis done systematically for many sites may reveal overall trends.

#### 6.1.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. The weight of “axle group” was evaluated separately for tandem axles on tractors and on trailers. The separate evaluation was carried out because the tandem axles on trailers may have different dynamic response to loads than tandem axles on tractors.

The measurement errors were statistically attributed to the following variables or factors:

- Truck type. Primary truck and Secondary truck.
- Truck test speed. Truck test speed ranged from 59 to 73 mph.
- Pavement temperature. Pavement temperature ranged from 87.0 to 128.3 degrees Fahrenheit.

### 6.1.2 Results

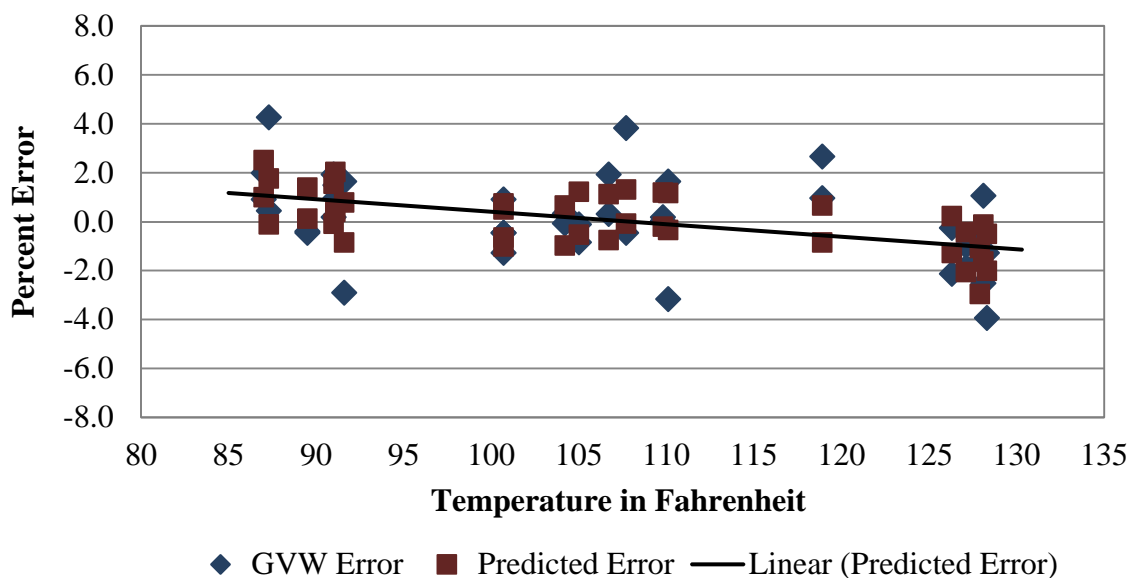
For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 6-1. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables (speed, temperature, and truck type). The values of the t-distribution (for the regression coefficients) given in Table 6-1 are for the null hypothesis that assumes that the regression coefficients are equal to zero. The p-value reported in Table 6-1 is for the probability that the regression coefficient, given in Table 5-5, occur by chance alone.

**Table 6-1 – Table of Regression Coefficients for Measurement Error of GVW**

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value (p-value)
Intercept	13.3812	4.0739	3.2846	0.0023
Speed	-0.1220	0.0528	-2.3085	0.0268
Temp	-0.0581	0.0149	-3.8938	0.0004
Truck	1.5119	0.4247	3.5596	0.0011

The lowest probability value given in Table 5-15 was 0.0004 for temperature. This means that there is about a 0.04 percent chance that the value of regression coefficient for temperature (-0.0581) can occur by chance alone. However, the value of the regression coefficient is close to 0 meaning that this relation has very low practical significance. Overall, speed and truck type have the most significant effect on the GVW measurement errors.

The relationship between temperature and GVW measurement errors is shown in Figure 6-1. The figure includes a trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 6-1 provides quantification and statistical assessment of the relationship.



**Figure 6-1 – Influence of Temperature on the Measurement Error of GVW**

The quantification of the relationship is provided by the value of the regression coefficient, in this case -0.0581 (in Table 6-1). This means, for example, that for a 10 degree change in temperature, the error is changed by about -0.5 percent ( $-0.0581 \times 10$ ). The statistical assessment of the relationship is provided by the probability value of the regression coefficient (0.0004) and is statistically significant.

### 6.1.3 Summary Results

Table 6-2 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 6-2 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).



**Table 6-2 – Summary of Regression Analysis**

Parameter	Factor					
	Speed		Temperature		Truck type	
	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)	Regression coefficient	Probability value (p-value)
GVW	-0.1220	0.0268	-0.0581	0.0004	1.5119	0.0011
Steering axle	-	-	-	-	2.7741	0.0105
Tandem axle tractor	-0.3320	0.0053	-0.0507	0.1171	3.1567	0.0012
Tandem axle trailer	-	-	-0.0736	0.0192	-	-

#### 6.1.4 Conclusions

1. According to Table 6-2, speed had a statistically significant effect on GVW and tractor tandem axle measurement errors.
2. Temperature affected measurement error of tandem axles on the tractor and trailer and thus also the measurement error of the GVW. The regression coefficients ranged from -0.0736 for the trailer tandem axles to -0.0507 for the tandem axle on the tractor. The difference between regression coefficients obtained for different axle types and GVW was not statistically significant.
3. Truck type had statistically significant effect on GVW measurement errors at 0.0011 probability value. The regression coefficients for truck type in Table 6-2 represent the difference between the mean errors for the Primary and Secondary trucks. (Truck type is an indicator variable with values of 0 or 1).
4. Even though temperature, speed and truck type had statistically significant effect on measurement errors of some of the parameters, the practical significance of these effects on WIM system calibration tolerances was small and does not affect the validity of the validation.

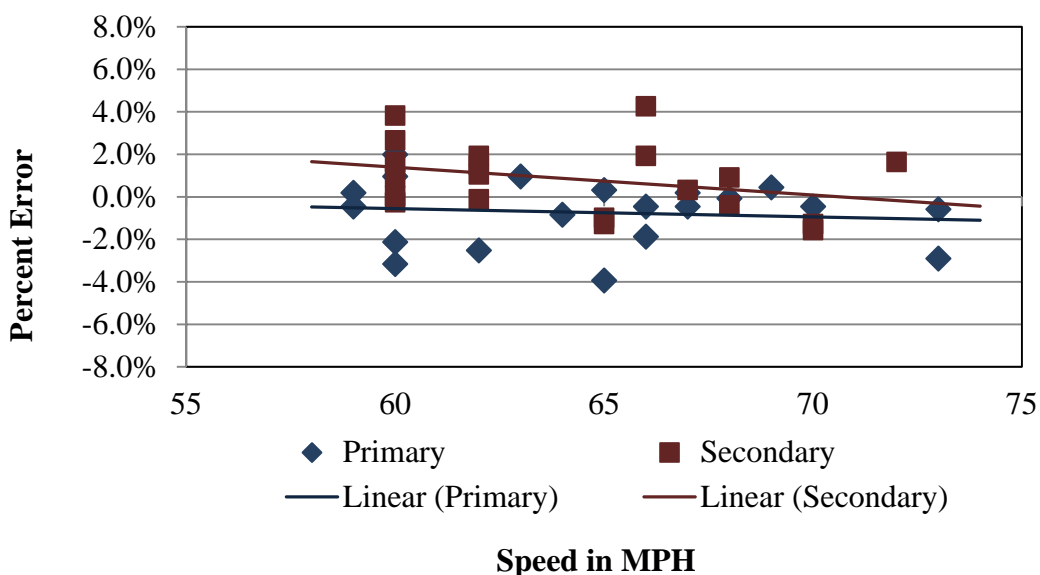
#### 6.1.5 Contribution of Two Trucks to Calibration

Calibration of WIM systems installed in LTPP lanes is carried out by adjusting calibration factors based on measurement errors of GVW obtained for calibration trucks. During the calibration process, the GVW measurement errors obtained for two calibration trucks are combined when calculating and setting calibration factors. Different calibration factors are used for different speed points (truck speeds). The question addressed in this section is: What would

be the calibration factors (calibration results) if only one truck (either Primary or Secondary) was used?

The contribution of using Primary and Secondary trucks for the calibration of the WIM system is illustrated using Figure 6-2 and supported by the associated statistical analysis. It is noted that the influence of pavement temperature is not directly used in the calibration process and thus not considered in this analysis.

Figure 6-2 shows that speed had similar influences on the GVW measurement for each truck, with the Secondary trucks showing slightly higher negative correlation with speed. Combined, the overall GVW error dependency on speed was statistically significant for less than 3 percent (by chance alone) level of significance (p-value was 0.0268). However, its influence is very low based on low value of regression coefficient resulting in additional negative 1.2 percent error for each 10 mph speed increase.



**Figure 6-2– Influence of Speed on the GVW Measurement Error of Primary and Secondary Trucks**

The use of two calibration trucks provided verification of the trends and speeded up the time required to obtain 40 pre-validation runs. For this site, the use of only one of the trucks (Primary or Secondary) would have resulted in different verification and calibration results, based on the different correlations between speed and GVW errors for the two trucks. As shown in Table 6-3, the mean errors for each of the weight parameters is different for each of the trucks, however, the differences for GVW cancel one another out.

**Table 6-3 – Post-Validation Results by Truck Type – 15-Aug-13**

Parameter	95% Confidence Limit of Error	Primary	Secondary
Steering Axles	$\pm 20$ percent	$-3.9 \pm 6.0\%$	$-1.1 \pm 7.3\%$
Tandem Axles	$\pm 15$ percent	$-0.3 \pm 4.8\%$	$1.5 \pm 7.4\%$
GVW	$\pm 10$ percent	$-0.7 \pm 3.2\%$	$0.8 \pm 3.4\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$-1.3 \pm 3.6$ ft	$0.7 \pm 1.8$ ft
Vehicle Speed	$\pm 1.0$ mph	$1.4 \pm 2.9$ mph	$1.0 \pm 0.3$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$-0.2 \pm 0.3$ ft	$-0.1 \pm 0.3$ ft

## 6.2 Misclassification Analysis

A post-visit analysis was conducted on the truck misclassifications identified during the post-validation conducted in the field. For this site, a total of 7 vehicles, including 4 heavy trucks (6 – 13) were misclassified by the equipment. The truck misclassifications all involved Class 9 trucks, where one Class 9 was identified as a Class 10 by the equipment and the other 3 were unclassified (Class 15). It should be noted that all four of these vehicle were consecutive in order as they passed over the WIM system and so it is believed that a temporary system fault was the cause. According to the Sheet 20, these vehicles were identified as vehicle numbers 5223, 5230, 5235 and 5236 by the system. The capture of the real-time records for these vehicles is provided in Figure 6-3.

5223 71 mph	Lane: 4	2013.08.15	12:20:32	T:116	V:00		
Veh-Code 10	Total 1	2	3	4	5	6	
Weight left (kips)	22.7	5.4	4.3	3.7	4.5	3.8	1.1
Weight right (kips)	18.4	4.9	3.1	3.4	3.4	2.7	0.9
Weight (kips)	41.1	10.3	7.4	7.1	7.9	6.5	2.0
Spacings (feet)	75.0	17.4	4.2	30.6	3.8	8.2	
5230 71 mph	Lane: 4	2013.08.15	12:20:50	T:116	V:00		
Veh-Code 15	Total 1	2	3	4			
Weight left (kips)	8.1	2.3	2.0	1.9	2.0		
Weight right (kips)	8.5	2.3	1.6	2.7	2.0		
Weight (kips)	16.6	4.6	3.5	4.6	3.9		
Spacings (feet)	36.6	12.2	8.2	13.2			
5235 62 mph	Lane: 4	2013.08.15	12:21:08	T:116	V:09		
Veh-Code 15	Total 1	2	3	4			
Weight left (kips)	32.6	7.4	11.3	10.4	3.5		
Weight right (kips)	27.4	6.8	9.4	8.1	3.2		
Weight (kips)	14.2	20.6	18.5	6.7			
Spacings (feet)	19.7	0.5	1.1	15.1			
5236 72 mph	Lane: 4	2013.08.15	12:21:12	T:116	V:80		
Veh-Code 15	Total 1	2	3				
Weight left (kips)	9.4	3.8	4.0	1.6			
Weight right (kips)	6.8	3.5	2.2	1.1			
Weight (kips)	16.2	7.3	6.1	2.8			
Spacings (feet)	67.3	4.3	37.1				

### Figure 6-3 – Vehicle Records of Class 9 Misclassifications

The video capture of the trucks is provided in Photo 6-1 through Photo 6-4. As the photos illustrate, all of the misclassification involved Class 9 vehicles.

Vehicle number 5223 was classified as a Class 10 by the equipment. As shown in Figure 6-3, the record indicates that an extra axle was captured by the system for this vehicle. The cause for this cannot be determined without further investigation that is not within the scope of the validation team's work. However, the cause of the problem may be related to the Overall Length measurement issue.



**Photo 6-1 – Vehicle Number 5223**

For vehicles 5230, 5235, and 5236, it appears that 1 or 2 of the axles were not captured by the system, as shown in Figure 6-3. The cause for this cannot be determined without further investigation that is not within the scope of the validation team's work.



**Photo 6-2 – Vehicle Number 5230**





**Photo 6-3 – Vehicle Number 5235**



**Photo 6-4 – Vehicle Number 5236**

## **6.3 Traffic Data Analysis**

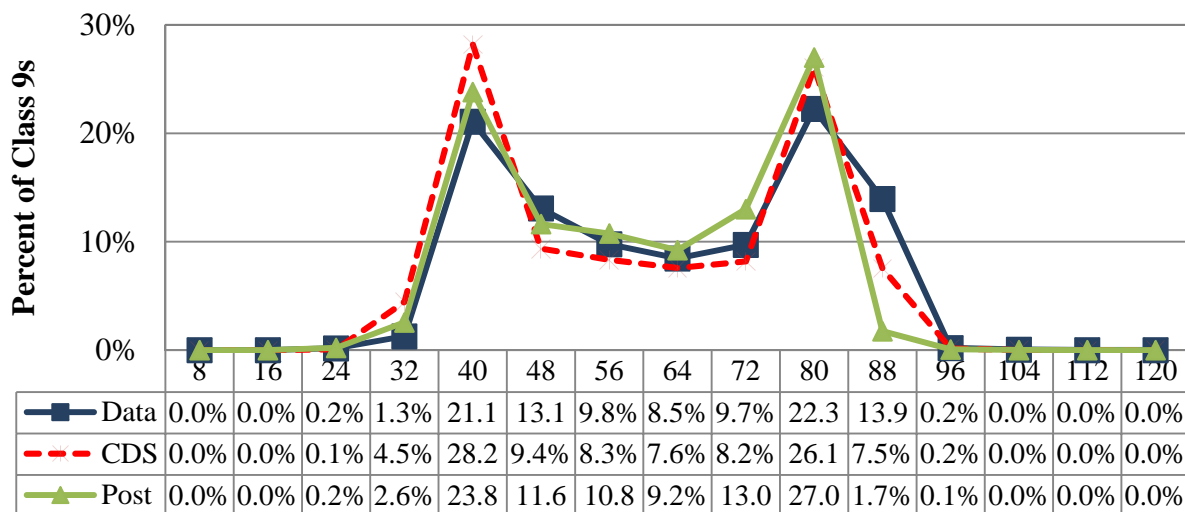
### **6.3.1 Average GVW and Steering Axle Weights**

As a result of the Post-Visit Traffic Data Analysis, it appears that the calibration adjustments brought the average GVW and Steering Axle weights for the site in line with the Comparison Data Set from January 27, 2011, as shown in Table 6-4**Error! Reference source not found..**

**Table 6-4 – Average GVW and Steering Axle Weights**

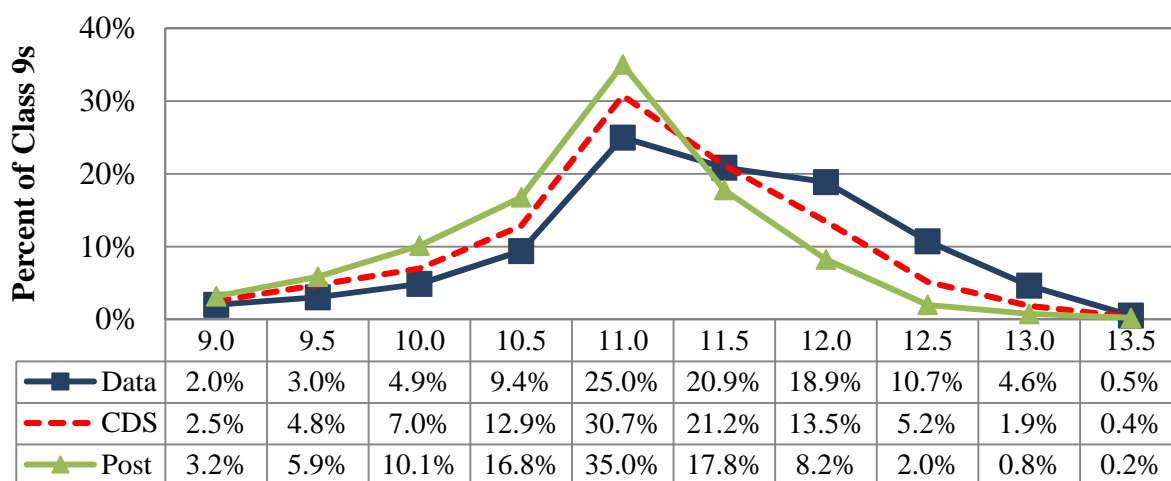
Data Set	Date	Average GVW (kips)	Average Steering Axle (kips)
Comparison Data Set	January 27, 2011	56.3 kips	10.9 kips
Pre-Visit Sample	August 14, 2013	59.6 kips	11.2 kips
Post-Visit Sample	September 20, 2013	56.6 kips	10.7 kips

As shown in Figure 6-4, the loaded GVW peak for the post-visit data is similar to the Comparison Data Set.



**Figure 6-4 – Post-Visit GVW Comparison**

As shown in Figure 6-5, the loaded front axle weights are for the post-visit data is similar to the Comparison Data Set.



**Figure 6-5 – Post-Visit Front Axle Comparison**

### 6.3.2 Imbalance

The left-to-right imbalance percentage cannot be developed from test trucks runs due to the limited sample. Consequently, free flow truck traffic must be used.

A post-visit data analysis was conducted using the data immediately following the date of the validation. The results of the post-visit imbalance analysis are presented in Table 6-5

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**Table 6-5 – Front Axle Weight Imbalance**

Data Set	Date	Left	Right	Imbalance	PCT
Pre-Visit Sample	August 14, 2013	5.87	5.35	Left	8.8%
Post-Visit Sample	September 20, 2013	5.42	5.26	Left	3.0%

As shown in the table, the pre-visit data showed that the left side weights were 8.8 greater than the right side weights. The post-visit data shows that the left weights are 3.0 percent greater than the right side weights. The post-visit imbalance is not significant. Therefore, it is not recommended that the calibration factors be adjusted as presented in **Error! Reference source not found..**

### 6.3.3 WIM System Factor Adjustments

Since the average GVW and steering axle weights provided during the Post-Visit data analysis are reasonably similar to those provided by the Comparison Data Set, and the front axle does not demonstrate a significant imbalance, no adjustments to the WIM system factors are recommended.



## 7 Previous WIM Site Validation Information

The information reported in this section provides a summary of the performance of the WIM equipment since it was installed or since the first validation was performed on the equipment. The information includes historical data on weight and classification accuracies as well as a comparison of post-validation results.

### 7.1 Classification

The information in Table 7-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

**Table 7-1 – Classification Validation History**

Date	Misclassification Percentage by Class											Pct Unclass
	3	4	5	6	7	8	9	10	11	12	13	
26-Apr-05	-	-	13	0	-	40	5	25	0	0	-	0
27-Apr-05	-	100	33	0	-	67	6	-	-	-	25	0
9-May-06	-	100	38	50	-	75	5	0	-	-	-	0
10-May-06	-	0	0	0	0	0	0	0	0	0	0	0
6-Nov-07	-	0	0	0	-	20	3	50	-	-	-	0
7-Nov-07	-	0	15	0	-	-	1	100	-	-	-	0
9-Dec-08	-	67	17	20	-	75	0	0	-	-	0	0
10-Dec-08	-	100	15	0	-	100	1	0	0	0	-	0
25-Jan-11	-	0	4	14	0	0	3	0	0	0	0	0
14-Aug-13	0	0	0	0	0	0	0	0	0	0	0	0
15-Aug-13	100	0	0	0	0	33	4	0	0	0	0	2.7

### 7.2 Weight

Table 7-2 data was extracted from the previous validation and was updated to include the results of this validation. The table provides the mean error and standard deviation for GVW, steering and single axles and tandems for prior pre- and post-validations.

**Table 7-2 – Weight Validation History**

Date	Mean Error and 2SD		
	GVW	Single Axles	Tandem
26-Apr-05	0.5 ± 4.1	-2.5 ± 5.1	0.5 ± 6.9
27-Apr-05	1.4 ± 3.9	-4.9 ± 6.3	1.8 ± 6.6
9-May-06	0.5 ± 4.8	-2.4 ± 4.4	1.2 ± 12.3
10-May-06	-0.5 ± 3.6	-2.6 ± 5.6	-0.1 ± 8.9
6-Nov-07	1.0 ± 3.2	-1.5 ± 6.3	1.5 ± 5.7
7-Nov-07	1.3 ± 3.6	-1.2 ± 6.3	1.8 ± 5.7
9-Dec-08	0.7 ± 2.8	-3.1 ± 5.9	1.4 ± 5.5
10-Dec-08	0.2 ± 2.8	-2.7 ± 7.1	0.6 ± 5.0
25-Jan-11	0.3 ± 2.8	-2.4 ± 6.7	1.5 ± 3.6
14-Aug-13	0.1 ± 6.9	0.3 ± 16.6	1.0 ± 10.1
15-Aug-13	0.0 ± 3.6	-2.5 ± 7.0	0.5 ± 6.4

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated, with exception of August 14 pre-validation values that showed much lower precision. This could be attributed to the extended period of time that lapsed between subsequent validation and calibration visits – over 2.5 years. The table also demonstrates the effectiveness of the validations in maintaining the weight estimations within LTPP SPS WIM equipment tolerances and confirms the benefit of conducting these activities with 12-18 months frequency.

## 8 Validation of the Kistler WIM System

A WIM validation was performed on August 14, 2013 on the Kistler WIM System located in the LTPP lane at the Texas SPS-1 site located on route US-281, milepost 34.0, 9.2 miles north of SR 186.

This site was installed on February, 2005. The in-road sensors are installed in the southbound, righthand driving lane. The site is equipped with quartz WIM sensors and an IRD iSINC WIM controller. The in-road sensors are installed immediately following the LTPP SPS-1 bending plate sensors. The lane is identified as lane 4 in the WIM controller.

The equipment is in working order. None of the in-road sensors show signs of damage or excessive wear and appear to be fully secured in the pavement.

### 8.1 Validation

The 40 Validation test truck runs were conducted on August 14, 2013, beginning at approximately 10:25 AM and continuing until 4:24 PM.

Test truck speeds varied by 18 mph, from 54 to 72 mph. The measured validation pavement temperatures varied 32.0 degrees Fahrenheit, from 101.0 to 133.0. The sunny weather conditions provided the desired minimum 30 degree temperature range.

Table 5-9 is a summary of the validation results. Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is not providing research quality loading data for GVW. The site also does not meet the requirements for Overall Vehicle Length.

**Table 8-1 – Validation Overall Results – 14-Aug-13**

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	$\pm 20$ percent	$3.6 \pm 14.0\%$	Pass
Tandem Axles	$\pm 15$ percent	$2.4 \pm 11.5\%$	Pass
GVW	$\pm 10$ percent	$4.4 \pm 9.9\%$	FAIL
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$1.9 \pm 1.1$ ft	FAIL
Axle Length	$\pm 0.5$ ft [150mm]	$0.1 \pm 0.3$ ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was  $0.9 \pm 3.2$  mph, which is greater than the  $\pm 1.0$  mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.1 feet, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within similar acceptable ranges.

### 8.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 75 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-10.

**Table 8-2 – Validation Results by Speed – 14-Aug-13**

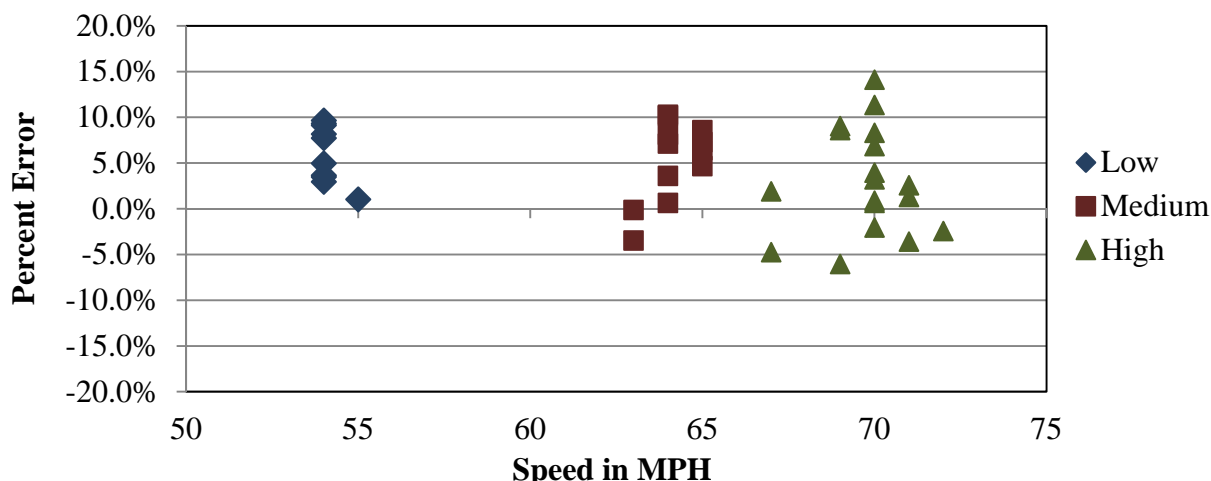
Parameter	95% Confidence Limit of Error	Low	Medium	High
		54.0 to 60.0 mph	60.1 to 66.1 mph	66.2 to 72.0 mph
Steering Axles	$\pm 20$ percent	$4.9 \pm 14.4\%$	$6.0 \pm 15.3\%$	$1.3 \pm 14.3\%$
Tandem Axles	$\pm 15$ percent	$6.6 \pm 8.7\%$	$5.3 \pm 11.6\%$	$3.5 \pm 13.9\%$
GVW	$\pm 10$ percent	$6.0 \pm 7.1\%$	$5.3 \pm 9.6\%$	$3.0 \pm 12.1\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$1.9 \pm 1.3$ ft	$2.2 \pm 1.0$ ft	$1.7 \pm 1.1$ ft
Vehicle Speed	$\pm 1.0$ mph	$2.9 \pm 0.7$ mph	$-0.5 \pm 2.7$ mph	$0.7 \pm 2.0$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$0.2 \pm 0.3$ ft	$0.1 \pm 0.2$ ft	$0.1 \pm 0.3$ ft

From the table, it can be seen that the WIM equipment over estimates all weights at all speeds. There does appear to be a relationship between Tandem and GVW weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following paragraphs.

#### 8.1.1.1 GVW Errors by Speed

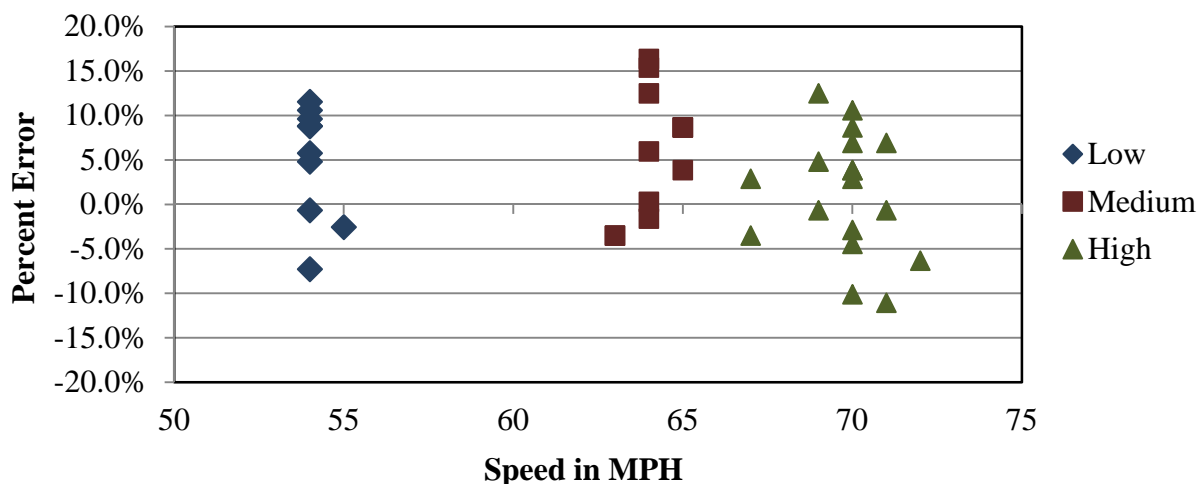
As shown in Figure 5-12, the equipment generally overestimated GVW at all speeds. The range in error increases as speed increases. At low speeds, overestimation was observed for all truck runs, while at high speed, GVW measurements were both under and overestimated.



**Figure 8-1 – Validation GVW Errors by Speed – 14-Aug-13**

#### 8.1.1.2 Steering Axle Weight Errors by Speed

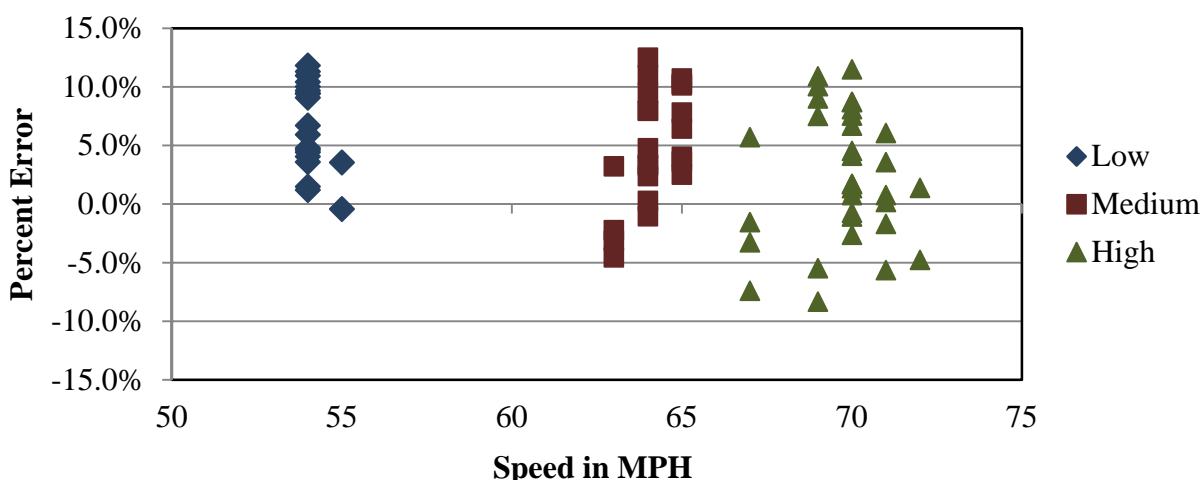
As shown in Figure 5-13, the equipment overestimates steering axle weights at the low and medium speeds. The range in error is similar for the three speed groups.



**Figure 8-2 – Validation Steering Axle Weight Errors by Speed – 14-Aug-13**

#### 8.1.1.3 Tandem Axle Weight Errors by Speed

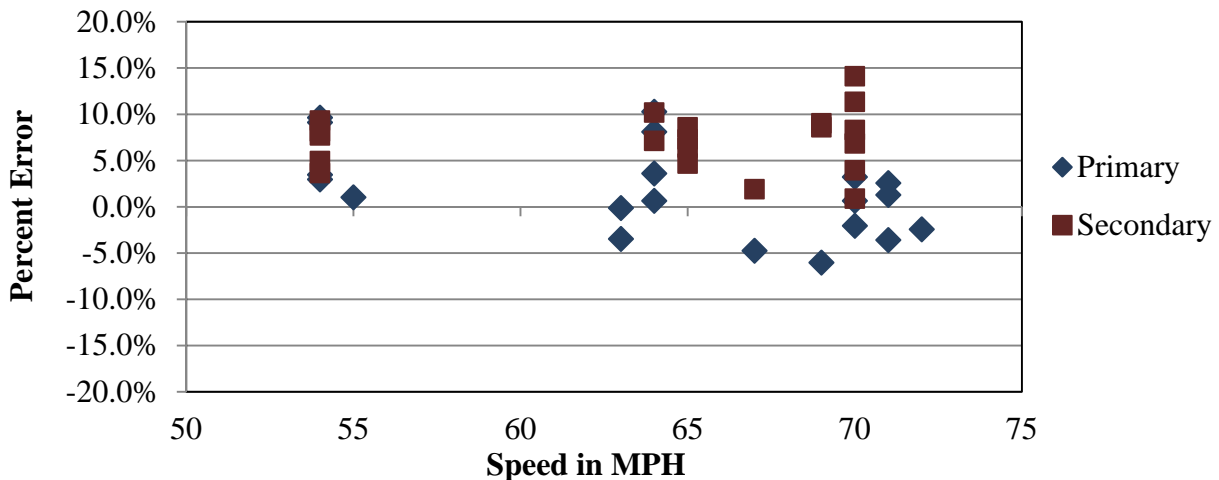
As shown in Figure 5-14, the equipment overestimated tandem axle weights at the low and medium speeds. The range in error appears to increase as speed increases.



**Figure 8-3 – Validation Tandem Axle Weight Errors by Speed – 14-Aug-13**

#### 8.1.1.4 GVW Errors by Speed and Truck Type

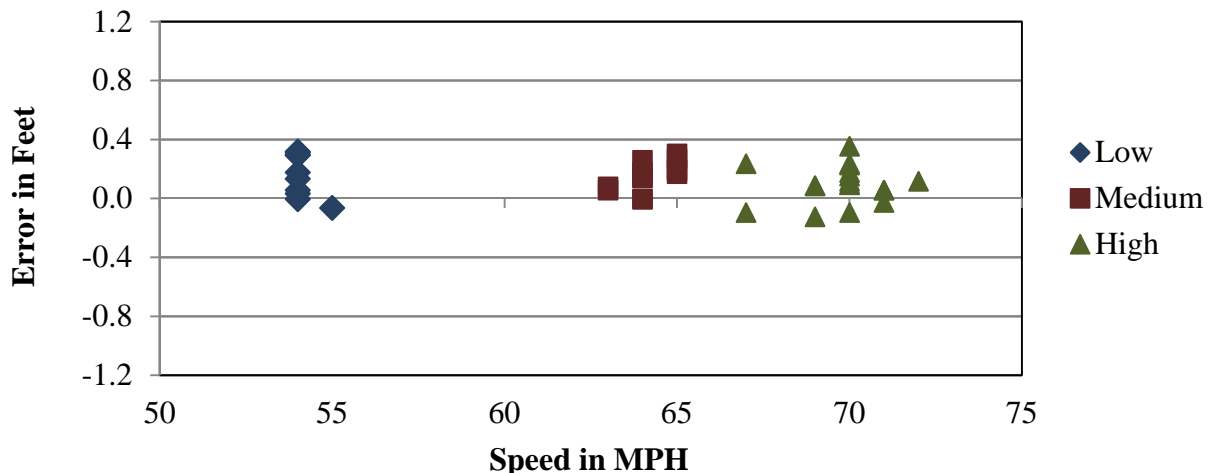
It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment bias is different for the heavily loaded (Primary) truck and the partially loaded (Secondary) truck. GVW for the Secondary truck is increasingly overestimated as speed increases while GVW bias for the Primary truck remained very low and constant across the range of speeds.



**Figure 8-4 – Validation GVW Error by Truck and Speed – 14-Aug-13**

#### 8.1.1.5 Axle Length Errors by Speed

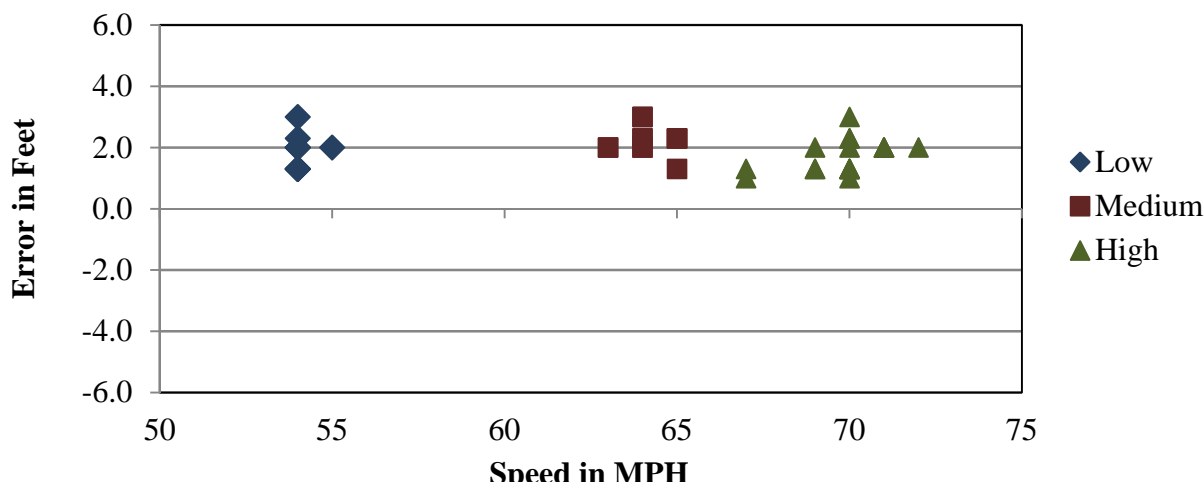
For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error was from -0.1 feet to 0.4 feet. Distribution of errors is shown graphically in Figure 5-16.



**Figure 8-5 – Validation Axle Length Error by Speed – 14-Aug-13**

#### 8.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment overestimates overall length consistently over the entire range of speeds, with errors ranging from 1.0 to 3.0 feet. Distribution of errors is shown graphically in Figure 5-17.



**Figure 8-6 – Validation Overall Length Error by Speed – 14-Aug-13**

#### 8.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 32.0 degrees, from 101.0 to 133.0 degrees Fahrenheit. Although the desired 30-degree temperature range was met, the validation test runs are reported under two temperature groups – low and high, as shown in Table 5-11 below.

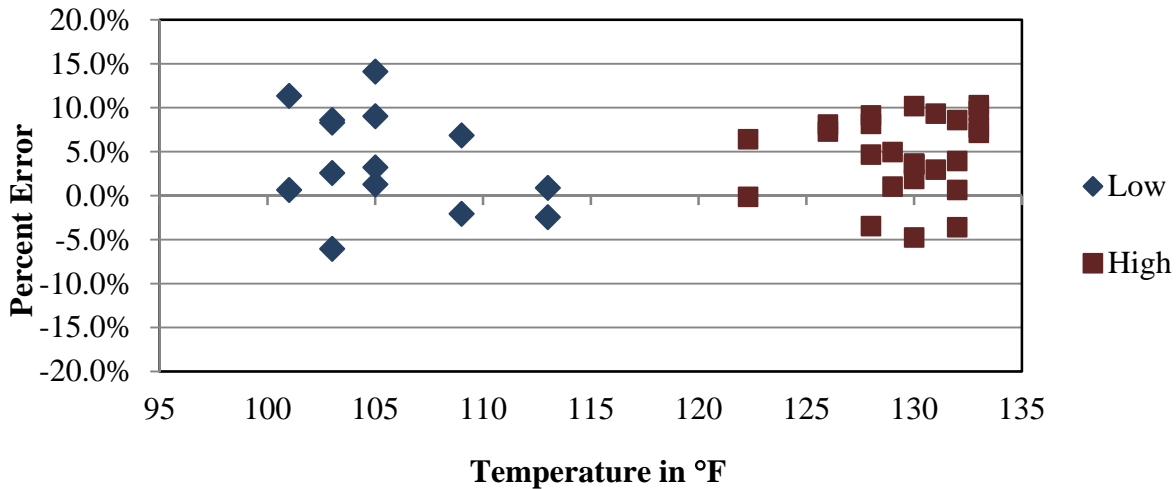
**Table 8-3 – Validation Results by Temperature – 14-Aug-13**

Parameter	95% Confidence Limit of Error	Low	High
		101.0 to 115 degF	115.1 to 133.0 degF
Steering Axles	$\pm 20$ percent	$2.4 \pm 14.5\%$	$4.3 \pm 14.5\%$
Tandem Axles	$\pm 15$ percent	$4.7 \pm 14.2\%$	$4.9 \pm 10.8\%$
GVW	$\pm 10$ percent	$4.0 \pm 12.6\%$	$4.6 \pm 9.1\%$
Vehicle Length	$\pm 3.0$ percent (1.7 ft)	$1.8 \pm 1.2$ ft	$2.0 \pm 1.2$ ft
Vehicle Speed	$\pm 1.0$ mph	$0.7 \pm 1.8$ mph	$1.0 \pm 3.9$ mph
Axle Length	$\pm 0.5$ ft [150mm]	$0.1 \pm 0.3$ ft	$0.1 \pm 0.3$ ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle weights, and axle group weights.

#### 8.1.2.1 GVW Errors by Temperature

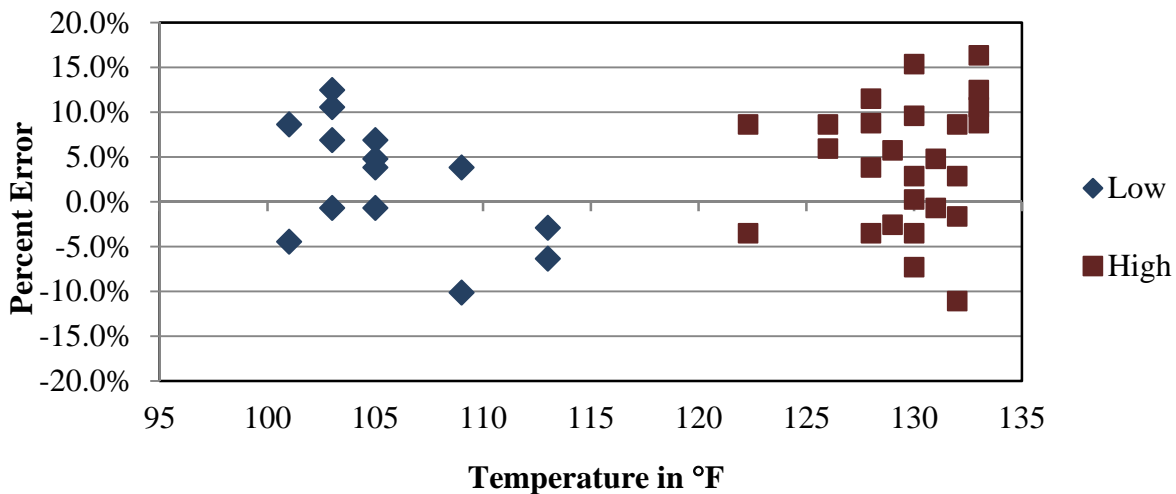
From Figure 5-18, it can be seen that the equipment generally overestimates GVW with similar bias across the range of temperatures observed in the field. The range in error appears to be slightly wider at the lower temperatures.



**Figure 8-7 – Validation GVW Errors by Temperature – 14-Aug-13**

#### 8.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-19 shows that the WIM equipment appears to overestimate steering axle weights with similar bias across the range of temperatures observed in the field. The range in error is greater at the higher temperatures.

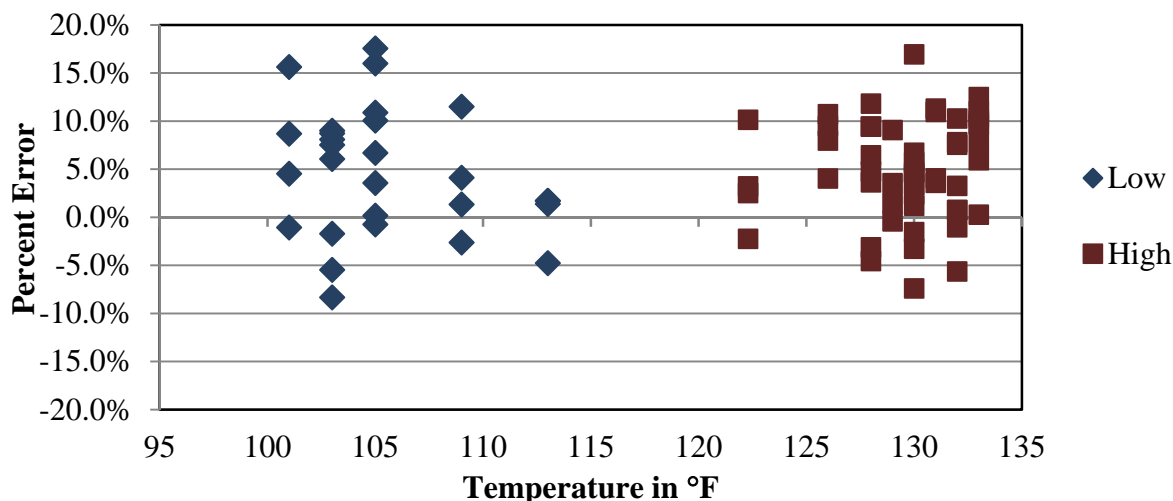


**Figure 8-8 – Validation Steering Axle Weight Errors by Temperature – 14-Aug-13**



### 8.1.2.3 Tandem Axle Weight Errors by Temperature

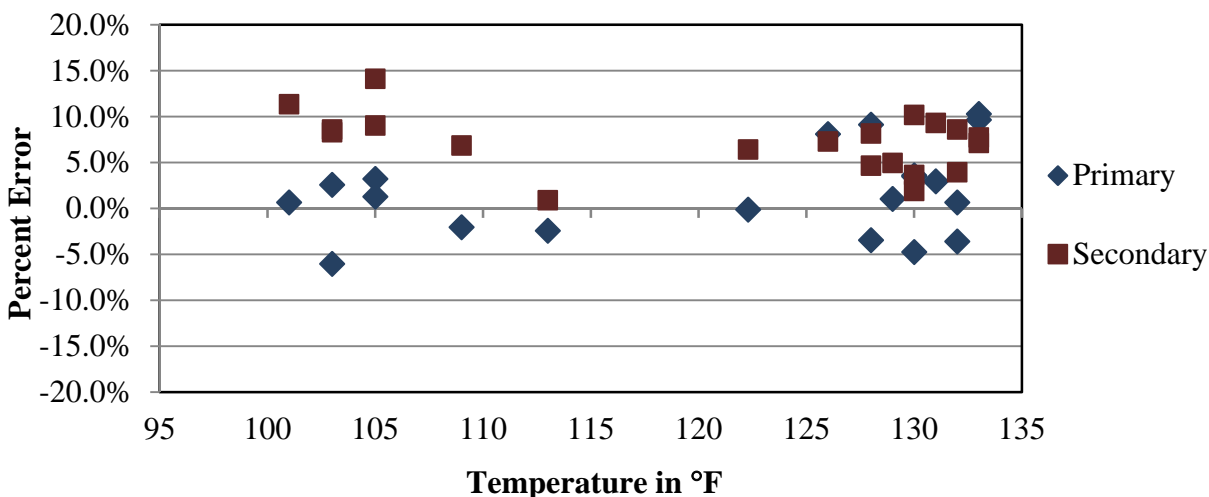
As shown in Figure 5-20, the WIM equipment appears to overestimate tandem axle weights with similar bias across the range of temperatures observed in the field. The range in tandem axle errors is wider at the lower temperatures.



**Figure 8-9 – Validation Tandem Axle Weight Errors by Temperature – 14-Aug-13**

### 8.1.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, GVW measurement errors for the tests trucks is different for the two temperature groups. GVW for the Secondary truck is overestimated at all temperatures.



**Figure 8-10 – Validation GVW Error by Truck and Temperature – 14-Aug-13**

Although the site was not providing research quality loading data for GVW, the on-site TXDOT personnel did not want to adjust the site parameters to compensate for the errors. Consequently, the calibration and post-validation were not performed.

### 8.1.3 Final WIM System Compensation Factors

The final factors left in place at the conclusion of the validation are provided in Table 5-15.

**Table 8-4 – Final Factors**

Speed Point	MPH	Left		Right	
		1	3	2	4
88	55	3150	3150	3300	3300
96	60	3075	3075	3240	3240
104	65	3075	3075	3240	3240
112	70	3000	3000	3100	3100
120	75	3000	3000	3100	3100
Axle Distance (cm)		185			
Dynamic Comp (%)		100			
Loop Width (cm)		246			

## 9 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
  - Equipment
  - Test Trucks
  - Pavement Condition
- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Pre-validation Sheet 20 – Classification and Speed Study
- Post-validation Sheet 20 – Classification and Speed Study

Additional information is available upon request through LTPP INFO at [ltpinfo@dot.gov](mailto:ltpinfo@dot.gov), or telephone (202) 493-3035. This information includes:

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Validation Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 24A/B – Site Photograph Logs
- Updated Handout Guide

# WIM System Field Calibration and Validation - Photos

Texas, SPS-1

SHRP ID: 480100

Validation Date: August 16, 2013





**Photo 1 – Cabinet Exterior**



**Photo 2 – Cabinet Interior (Front)**



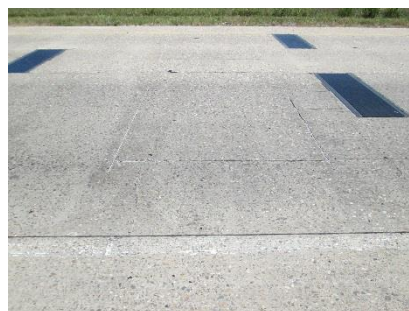
**Photo 3 – Leading Loop**



**Photo 4 – Leading WIM Sensor**



**Photo 5 – Trailing WIM Sensor**



**Photo 6 – Trailing Loop Sensor**



**Photo 7 – Power Service Box**



**Photo 8 – Telephone Service Box**





**Photo 9 – Downstream**



**Photo 10 – Upstream**



**Photo 11 – Truck 1**



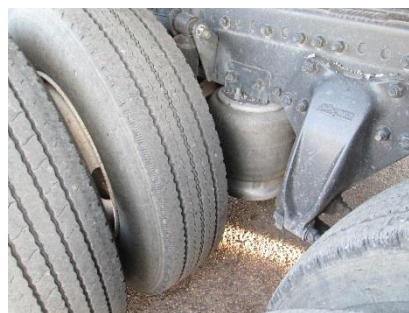
**Photo 12 – Truck 1 Tractor**



**Photo 13 – Truck 1 Trailer and Load**



**Photo 14 – Truck 1 Suspension 1**



**Photo 15 – Truck 1 Suspension 2**



**Photo 16 – Truck 1 Suspension 3**



**Photo 17 – Truck 1 Suspension 4**



**Photo 18 – Truck 1 Suspension 5**



**Photo 19 – Truck 2**



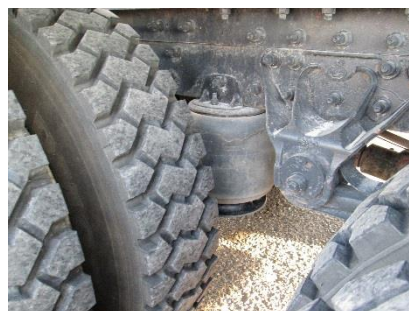
**Photo 20 – Truck 2 Tractor**



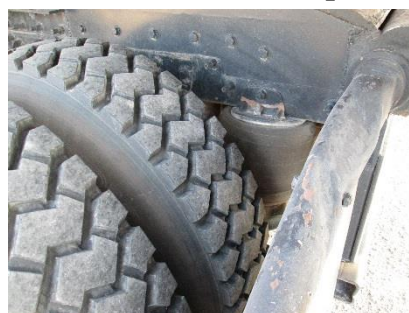
**Photo 21 – Truck 2 Trailer and Load**



**Photo 22 – Truck 2 Suspension 1**



**Photo 23 – Truck 2 Suspension 2**



**Photo 24 – Truck 2 Suspension 3**



**Photo 25 – Truck 2 Suspension 4**



**Photo 26 – Truck 2 Suspension 5**



<b>Traffic Sheet 16</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SITE CALIBRATION SUMMARY</b>	STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/14/2013
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### SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 8/14/13
2. TYPE OF EQUIPMENT CALIBRATED: Both
3. REASON FOR CALIBRATION: LTPP Validation
4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE (Select all that apply):
- a. Inductance Loops c.
- b. Bending Plates d.
5. EQUIPMENT MANUFACTURER: IRD DAW

### WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks
- Number of Trucks Compared:
- Number of Test Trucks Used: 2
- Passes Per Truck: 21
- |          | Type     | Drive Suspension    | Trailer Suspension  |
|----------|----------|---------------------|---------------------|
| Truck 1: | <u>9</u> | <u>air</u>          | <u>air</u>          |
| Truck 2: | <u>9</u> | <u>steel spring</u> | <u>steel spring</u> |
| Truck 3: | <u></u>  | <u></u>             | <u></u>             |

### 7. SUMMARY CALIBRATION RESULTS (expressed as a %):

Mean Difference Between -

Dynamic and Static GVW:	<u>0.1%</u>	Standard Deviation:	<u>3.4%</u>
Dynamic and Static Single Axle:	<u>0.3%</u>	Standard Deviation:	<u>8.2%</u>
Dynamic and Static Double Axles:	<u>1.0%</u>	Standard Deviation:	<u>5.0%</u>

### 8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED: 3

### 9. DEFINE SPEED RANGES IN MPH:

		Low		High	Runs	
a.	<u>Low</u>	-	<u>52.0</u>	to	<u>59.0</u>	<u>12</u>
b.	<u>Medium</u>	-	<u>59.1</u>	to	<u>66.1</u>	<u>14</u>
c.	<u>High</u>	-	<u>66.2</u>	to	<u>73.0</u>	<u>16</u>
d.	<u></u>	-	<u></u>	to	<u></u>	<u></u>
e.	<u></u>	-	<u></u>	to	<u></u>	<u></u>

<b>Traffic Sheet 16</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SITE CALIBRATION SUMMARY</b>	STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/14/2013
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10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 814

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

**CLASSIFIER TEST SPECIFICS**

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	<u>0.0</u>	FHWA Class	<u>        </u>	-	<u>        </u>
FHWA Class 8:	<u>0.0</u>	FHWA Class	<u>        </u>	-	<u>        </u>
		FHWA Class	<u>        </u>	-	<u>        </u>
		FHWA Class	<u>        </u>	-	<u>        </u>

Percent of "Unclassified" Vehicles: 0.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort:	<u>Greg Helman</u>
Contact Information:	Phone: <u>717-975-3550</u>
	E-mail: <u><a href="mailto:ghelman@ara.com">ghelman@ara.com</a></u>

<b>Traffic Sheet 16</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SITE CALIBRATION SUMMARY</b>	STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/15/2013
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### SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 8/15/13
2. TYPE OF EQUIPMENT CALIBRATED: Both
3. REASON FOR CALIBRATION: LTPP Validation
4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE (Select all that apply):
- a. Inductance Loops c.
- b. Bending Plates d.
5. EQUIPMENT MANUFACTURER: IRD DAW

### WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks
- Number of Trucks Compared:
- Number of Test Trucks Used: 2
- Passes Per Truck: 20
- |          | Type     | Drive Suspension    | Trailer Suspension  |
|----------|----------|---------------------|---------------------|
| Truck 1: | <u>9</u> | <u>air</u>          | <u>air</u>          |
| Truck 2: | <u>9</u> | <u>steel spring</u> | <u>steel spring</u> |
| Truck 3: | <u></u>  | <u></u>             | <u></u>             |

### 7. SUMMARY CALIBRATION RESULTS (expressed as a %):

Mean Difference Between -

Dynamic and Static GVW:	<u>0.0%</u>	Standard Deviation:	<u>1.8%</u>
Dynamic and Static Single Axle:	<u>-2.5%</u>	Standard Deviation:	<u>3.5%</u>
Dynamic and Static Double Axles:	<u>0.5%</u>	Standard Deviation:	<u>3.2%</u>

### 8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED: 3

### 9. DEFINE SPEED RANGES IN MPH:

		Low		High	Runs
a.	<u>Low</u>	<u>59.0</u>	to	<u>63.7</u>	<u>18</u>
b.	<u>Medium</u>	<u>63.8</u>	to	<u>68.4</u>	<u>15</u>
c.	<u>High</u>	<u>68.5</u>	to	<u>73.0</u>	<u>7</u>
d.	<u></u>	<u></u>	to	<u></u>	<u></u>
e.	<u></u>	<u></u>	to	<u></u>	<u></u>

<b>Traffic Sheet 16</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SITE CALIBRATION SUMMARY</b>	STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/15/2013
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10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 808

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

**CLASSIFIER TEST SPECIFICS**

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: \_\_\_\_\_

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	<u>-4.0</u>	FHWA Class	-	
FHWA Class 8:	<u>0.0</u>	FHWA Class	-	
		FHWA Class	-	
		FHWA Class	-	

Percent of "Unclassified" Vehicles: 2.7%

Validation Test Truck Run Set - Post

<b>Person Leading Calibration Effort:</b>	<u>Greg Helman</u>
<b>Contact Information:</b>	Phone: <u>717-975-3550</u>
	E-mail: <u><a href="mailto:ghelman@ara.com">ghelman@ara.com</a></u>

<b>Traffic Sheet 20</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SPEED AND CLASSIFICATION STUDIES</b>					STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/14/2013				
--	--	--	--	--	---	--	--	--	--

Count - 100      Time = 1:36:25      Trucks (4-15) - 100      Class 3s - 0

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
60	6	9862	57	6	69	9	10084	67	9
50	9	9876	49	9	76	9	10092	72	9
65	8	9890	65	8	75	9	10097	71	9
61	9	9891	59	9	68	6	10121	68	6
77	9	9899	75	9	63	9	10137	67	9
66	9	9900	64	9	69	9	10144	64	9
74	9	9912	74	9	65	9	10175	66	9
69	9	9914	67	9	75	9	10180	71	9
74	9	9921	73	9	65	9	10199	70	9
71	9	9926	68	9	75	9	10213	71	9
69	6	9955	68	6	69	5	10250	68	5
64	9	9957	64	9	67	9	10270	64	9
75	9	9976	75	9	62	9	10278	68	9
75	9	9978	73	9	63	9	10295	60	9
66	9	9979	66	9	70	9	10299	67	9
70	9	9982	68	9	60	8	10303	56	8
65	9	9985	61	9	60	9	10306	58	9
63	8	9986	60	8	64	9	10318	63	9
71	9	10008	71	9	66	9	10329	64	9
64	9	10020	63	9	58	9	10332	55	9
73	9	10027	69	9	75	9	10334	73	9
74	5	10035	73	5	69	8	10341	67	8
70	6	10040	68	6	67	9	10345	65	9
67	9	10048	65	9	66	9	10348	64	9
62	5	10051	61	5	67	6	10375	65	6

Sheet 1 - 0 to 50

Start: 18:53:00

Stop: 19:38:08

Recorded By: \_\_\_\_\_ ar \_\_\_\_\_

Verified By: \_\_\_\_\_ djw \_\_\_\_\_

Validation Test Truck Run Set - \_\_\_\_\_ Pre \_\_\_\_\_

<b>Traffic Sheet 20</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SPEED AND CLASSIFICATION STUDIES</b>					STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/14/2013				
--	--	--	--	--	---	--	--	--	--

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
63	9	10376	68	9	69	9	10672	69	9
62	9	10377	71	9	66	9	10680	63	9
70	9	10391	63	9	67	9	10682	67	9
71	9	10409	70	9	70	9	10687	66	9
65	9	10412	64	9	65	9	10702	64	9
62	9	10440	70	9	72	5	10705	67	5
66	9	10442	64	9	66	9	10713	64	9
70	9	10468	70	9	69	9	10715	66	9
70	9	10488	69	9	76	5	10717	75	5
63	8	10500	61	8	74	9	10719	74	9
71	9	10507	72	9	64	12	10723	71	12
70	9	10544	71	9	68	9	10734	66	9
70	9	10553	68	9	62	9	10735	61	9
76	5	10554	76	5	65	8	10736	64	8
72	9	10565	69	9	72	9	10743	70	9
70	5	10567	67	5	66	8	10759	64	8
65	9	10578	63	9	64	9	10765	61	9
56	9	10582	54	9	67	9	10774	67	9
68	9	10585	66	9	73	9	10778	72	9
69	9	10595	68	9	75	9	10779	73	9
65	9	10598	64	9	68	9	10780	65	9
70	5	10601	66	5	65	9	10784	67	9
61	9	10613	59	9	66	9	10801	65	9
63	11	10633	62	11	73	9	10806	72	9
66	9	10639	65	9	69	9	10828	67	9

Sheet 2 - 51 to 100

Start: 19:38:23

Stop: 20:29:25

Recorded By: \_\_\_\_\_ ar \_\_\_\_\_

Validation Test Truck Run Set - Pre

<b>Traffic Sheet 20</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SPEED AND CLASSIFICATION STUDIES</b>					STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/15/2013				
--	--	--	--	--	---	--	--	--	--

Count - 112      Time = 1:03:07      Trucks (4-15) - 110      Class 3s - 2

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
77	9	4651	76	9	66	9	4808	65	9
72	9	4658	70	9	65	9	4844	68	9
75	8	4665	64	8	67	9	4848	66	9
65	9	4667	63	9	62	9	4858	60	9
65	6	4673	65	6	69	8	4864	66	8
70	9	4681	68	9	64	9	4873	64	9
68	9	4686	66	9	71	9	4881	69	9
61	9	4687	59	9	70	9	4903	69	9
69	10	4693	68	10	59	5	4916	60	5
73	5	4698	71	5	69	9	4926	58	9
71	9	4713	73	9	69	9	4932	69	9
59	9	4716	56	9	68	9	4933	66	9
63	9	4721	61	9	64	9	4934	65	9
73	9	4735	72	9	68	9	4936	68	9
66	9	4737	64	9	70	5	4939	68	5
59	9	4744	55	9	68	9	4945	65	9
65	9	4746	55	9	64	9	4949	63	9
68	9	4748	65	9	68	11	4955	65	11
72	9	4752	64	9	64	9	4934	65	9
64	9	4755	61	9	68	9	4936	69	9
60	9	4766	63	9	76	5	5001	75	5
65	9	4792	68	9	73	9	5003	72	9
69	9	4795	69	9	64	9	5007	65	9
67	9	4802	66	9	70	9	5010	65	9
65	9	4805	65	9	68	9	5011	65	9

Sheet 1 - 0 to 50

Start: 11:31:56

Stop: 12:00:10

Recorded By: gah

Verified By: djw

Validation Test Truck Run Set - Post

<b>Traffic Sheet 20</b> <b>LTPP MONITORED TRAFFIC DATA</b> <b>SPEED AND CLASSIFICATION STUDIES</b>					STATE CODE: 48 SPS WIM ID: 480100 DATE (mm/dd/yyyy) 8/15/2013				
--	--	--	--	--	---	--	--	--	--

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
67	6	5022	65	6	5202	9	5202	71	9
65	9	5051	65	9	5206	9	5206	65	9
67	9	5056	65	9	71	10	5223	68	9
68	6	5068	68	6	71	15	5230	64	9
68	11	5074	68	11	2	15	5235	62	9
65	6	5089	65	6	72	15	5236	70	9
67	9	5097	65	9	73	9	5250	70	9
73	9	5100	72	9	65	9	5257	65	9
62	9	5101	70	9	65	8	5260	65	3
66	9	5107	66	9	69	9	5261	69	9
67	9	5109	66	9	76	9	5262	71	9
63	9	5117	66	9	66	9	5264	66	9
67	9	5133	67	9	72	9	5288	68	9
58	5	5149	3	8	67	9	5290	66	9
65	9	5155	65	9	75	9	5297	70	9
66	9	5160	65	9	69	9	5300	67	9
69	12	5164	69	12	71	9	5310	73	9
71	9	5167	70	9	75	9	5313	75	9
64	9	5172	62	9	71	9	5315	70	9
66	9	5181	64	9	63	9	5321	71	9
72	9	5182	70	9	64	9	5324	62	9
65	9	5184	64	9	71	9	5325	68	9
70	5	5186	68	5	71	5	5333	70	3
68	9	5193	66	9	67	9	5336	67	9
64	9	5199	64	9	73	9	5337	71	9

Sheet 2 - 51 to 100

Start: 12:01:42

Stop: 12:28:00

Recorded By:

ar

Validation Test Truck Run Set -

Post



<p align="center"><b>Traffic Sheet 20</b></p> <p align="center"><b>LTPP MONITORED TRAFFIC DATA</b></p> <p align="center"><b>SPEED AND CLASSIFICATION STUDIES</b></p>	<p>STATE CODE: 48</p> <p>SPS WIM ID: 480100</p> <p>DATE (mm/dd/yyyy) 8/15/2013</p>
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WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
66	9	5339	66	9					
69	9	5340	69	9					
68	9	5344	68	9					
75	9	5359	73	9					
67	9	5363	63	9					
72	9	5364	70	9					
68	9	5378	64	9					
66	9	5387	64	9					
76	9	5425	75	9					
70	9	5435	70	9					
69	9	5437	68	9					
65	9	5438	65	9					

Recorded By: gah 12:28:22 Verified By: djw 12:35:03

Validation Test Truck Run Set - Post